A PLATFORM FOR THE PROVISION OF CONTENT NETWORKS
BASED ON IMS, METADATA, PRESENCE AND P2P
TECHNOLOGIES

Eduardo Filipe Freire Ribeiro

Tese submetida como requisito parcial para obtenção do grau de
Mestre em Gestão de Sistemas de Informação

Orientador:
Ph.D., Rui Jorge H.C. Lopes, Professor Auxiliar

Instituto Superior de Ciências do Trabalho e da Empresa

[Setembro, 2008]
To my family, Ana and Inês
# Contents

1 Introduction, motivation and objectives .............................................. 1  
1.1 Introduction ............................................................................. 1  
1.2 Motivation ............................................................................. 2  
1.3 Objectives ............................................................................. 4  

2 Requirements and Use Cases .............................................................. 7  
2.1 Requirements ......................................................................... 7  
2.1.1 Communication Sub-system ................................................ 9  
2.1.2 Information System ................................................................. 9  
2.2 Use Cases .............................................................................. 10  

3 Enabling technologies .......................................................................... 13  
3.1 Multimedia framework (ISO/IEC MPEG-21) .................................. 13  
3.1.1 MPEG-21 vision and components ......................................... 14  
3.1.2 MPEG-7 ............................................................................. 20  
3.2 IP Multimedia Subsystem (IMS) .................................................. 23  
3.2.1 Service Layer ..................................................................... 24  
3.2.2 Control Layer ..................................................................... 24  
3.2.3 Transport Layer ................................................................... 25  
3.2.4 IMS protocols ...................................................................... 26  
3.2.5 IMS usage in the CN context ................................................ 26  
3.3 Presence Services ..................................................................... 28  
3.4 P2P Paradigm and tools .............................................................. 31  
3.5 Ontology concept and tools ........................................................ 33  

4 Design and Implementation ................................................................. 35  
4.1 Architecture ........................................................................... 35  
4.2 CN internal design ................................................................... 37  
4.2.1 CNAS Instance .................................................................. 38  
4.2.2 CNAS Data Model ............................................................... 39  
4.3 CNAS class implementation ....................................................... 39
## List of Figures

2.1 CN - Conceptual Framework .............................................. 8  
2.2 CN - Use Cases .......................................................... 10  
3.1 MPEG-21 Vision and Architectural Components [ISBK06] ............. 15  
3.2 MPEG-21 DID Model ..................................................... 16  
3.3 MPEG-21 DID Example .................................................. 17  
3.4 MPEG-21 DID Components .............................................. 18  
3.5 MPEG-21 DIA ............................................................. 19  
3.6 Using MPEG-7 MDS for the DI description ................................ 21  
3.7 MPEG-7 Architecture .................................................... 22  
3.8 IMS Architecture ........................................................ 24  
3.9 IMS - Service Point Trigger ............................................ 27  
3.10 IMS Initial Filter Criteria ............................................. 28  
3.11 Presence Model .......................................................... 29  
3.12 Presence Data Model .................................................... 30  
3.13 P2P - Overlay Network ............................................... 32  
3.14 CN Ontology .............................................................. 34  
4.1 Content Network - Layered Architecture ................................ 36  
4.2 Content Network - IMS Integration ................................... 37  
4.3 CN - Node instance design ............................................. 38  
4.4 CN - Node Implementation ............................................. 40  
4.5 CN Workflow Service State Diagram ................................... 43  
4.6 CN Notification Workflow Service ..................................... 44  
4.7 XSLT Adaption Process ................................................ 45  
4.8 CN UMA Profiler .......................................................... 46  
4.9 CN Ontology Implementation .......................................... 47  
4.10 CN Ontology Workflow Activity Diagram .............................. 48  
4.11 Use Case - Step 1 (Register Interests) ................................ 49  
4.12 CN SIP Message Header ............................................... 50  
4.13 CN Presence Information .............................................. 50  
4.14 CN DIA Message ........................................................ 51
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.15</td>
<td>CN DIA User Interests</td>
<td>51</td>
</tr>
<tr>
<td>4.16</td>
<td>CN Ontology Sample</td>
<td>52</td>
</tr>
<tr>
<td>4.17</td>
<td>CN Overlay</td>
<td>52</td>
</tr>
<tr>
<td>4.18</td>
<td>Use Case - Step 2 (Publishing Content)</td>
<td>53</td>
</tr>
<tr>
<td>4.19</td>
<td>CN DID Message for High Resolution</td>
<td>54</td>
</tr>
<tr>
<td>4.20</td>
<td>CN Presence Information 2</td>
<td>54</td>
</tr>
<tr>
<td>4.21</td>
<td>CN DID Message for Low Resolution</td>
<td>55</td>
</tr>
<tr>
<td>4.22</td>
<td>CN DID Message Semantic Description</td>
<td>55</td>
</tr>
<tr>
<td>4.23</td>
<td>CN Overlay</td>
<td>56</td>
</tr>
<tr>
<td>5.1</td>
<td>CN Demo Architecture</td>
<td>57</td>
</tr>
<tr>
<td>5.2</td>
<td>CN Middleware IMS Configuration</td>
<td>59</td>
</tr>
<tr>
<td>5.3</td>
<td>IPTV IMS Configuration</td>
<td>59</td>
</tr>
<tr>
<td>5.4</td>
<td>CN IPTV Server UML Activity Diagram</td>
<td>60</td>
</tr>
<tr>
<td>5.5</td>
<td>Content Demo MPEG-21 DID Descriptions</td>
<td>61</td>
</tr>
<tr>
<td>5.6</td>
<td>Content Demo MPEG-21 DIA Descriptions</td>
<td>61</td>
</tr>
<tr>
<td>5.7</td>
<td>CN IMS Client</td>
<td>62</td>
</tr>
<tr>
<td>5.8</td>
<td>CN IMS Client Demo</td>
<td>63</td>
</tr>
<tr>
<td>5.9</td>
<td>Non-functional Tests Architecture</td>
<td>64</td>
</tr>
<tr>
<td>5.10</td>
<td>CN Ontology Quality Test</td>
<td>66</td>
</tr>
<tr>
<td>5.11</td>
<td>CN Database Size</td>
<td>67</td>
</tr>
<tr>
<td>5.12</td>
<td>Query First Response Time</td>
<td>68</td>
</tr>
<tr>
<td>5.13</td>
<td>Query Last Response Time</td>
<td>69</td>
</tr>
</tbody>
</table>
Acknowledgments

Let me start from my family, thanks to you all for your understanding and ever-caring support during these long years of school and study, my fear is that i can’t love you enough in return for that.

With regard to this work, i am very grateful to Prof. Rui Lopes for his continuous effort in reviewing my ideas, proposals and results. He has contributed a lot to my growth of becoming a better person and student with his good balance between guidance and freedom. Finally, i would like to thank all the people who have been supportive in different ways during this work.
Abstract

The Internet is currently being designed and used in a way that is strongly influenced by inter-personal communications and content-based services. Content Networks, having presence and audiovisual metadata descriptions as central concepts, can play an important role in the provision of these services.

The CN represents thus a highly distributed information system, for the provision of content networks where users can interact with available content, based on the characteristics already mentioned (content descriptions, users preferences and presence).

Existing standards from the ISO/IEC MPEG (MPEG-7,-21) and IETF (PIDF, RPID) provide the technologies for these elementary features. This thesis contributes to the deployment of Content Networks by proposing a layered architecture where the IMS Multimedia Subsystem and P2P-based middleware in order to tackle the problem of terminal, networks heterogeneity and the integration of different presence and metadata tools.

The P2P-based middleware is used to construct autonomously self-organized, context and interest based communities by providing overlay infrastructures for the interconnection of different Content Networks components. The results obtained from implementing this architecture using Open IMS Core and Scribe open platforms show that the proposed architecture can be used for the creation and deployment of services on Content Networks and meet the requirements set for the design, implementation and deployment of novel multimedia content services.

An important research area that should be also considered is to investigate in the future how the proposed CN middleware infrastructure can be extended beyond audiovisual content metadata. One of the extensions to be explored is dynamic service creation, deployment and execution depending on context.

Keywords: Content Networks, Multimedia Framework, IMS, Metadata
Resumo

A Internet está actualmente a ser utilizada de uma forma que é fortemente influenciada pelas comunicações inter-pessoais e serviços baseados no conteúdo. As redes de conteúdos usam como conceitos centrais a informação de presença e a descrição do conteúdo, podendo assim desempenhar um papel importante na prestação desses serviços.

A rede de conteúdos representa, assim, um sistema de informação altamente distribuído baseado nas interações dos utilizadores com o conteúdo disponível, de acordo com as características já mencionadas (descrições dos conteúdos, preferências dos utilizadores e informação de presença).

As normas ISO / IEC MPEG (MPEG-7, -21) e IETF (PIDF, RPID) existentes proporcionam as tecnologias. Esta tese contribui para a implementação de redes de conteúdo, propondo uma plataforma onde a arquitectura IMS e P2P estão presentes de forma a resolver o problema da heterogeneidade de terminais, redes, e conteúdos.

A infraestrutura P2P é usada para construir autonomamente comunidades com os mesmos interesses e interligar os vários componentes da rede de conteúdo.

Os resultados obtidos com a implementação desta arquitectura usando as plataformas Open IMS Core e P2P Scribe mostram que a arquitectura proposta pode ser utilizada para a criação e implantação de novos serviços de conteúdos multimédia.

Uma importante área de investigação que deve ser considerada no futuro será como a plataforma apresentada pode ser adaptada para além dos conteúdos audiovisuais. Uma das extensões a ser explorada é a criação dinâmica de serviços dependendo do contexto.

**Keywords:** Redes de Conteúdo, Plataforma Multimédia, IMS, Metadados
Chapter 1

Introduction, motivation and objectives

1.1 Introduction

The topic of this thesis is the access to media content and its new possibilities fostered by new concepts such as universal media access, context, presence, and social networks. What is presented is a solution that tries to respond to the challenges found in discovering and accessing multimedia content.

Recent technologies and applications such as blogs, podcasting, videocasting and file sharing are increasingly being driven by community-based interactions and are gaining more and more importance in the Internet. The recent Web 2.0 paradigm has blurred the distinction between information providers and consumers. This paradigm shift has resulted in a huge popularity of Web sites that enable users to build social networks and share content. Currently, user generated content available on the Internet includes text in blogs [BANS04], photos and videos on sites such as Flickr [Sch06] or YouTube [CDL07]. Another important consequence of this type of user participation is that it is extremely dynamic in terms of its location and availability.

A relevant number of these sites foster social networking by allowing individuals with similar interests to form social groups, namely by providing tools for annotation of content. The tagging functionality [ZXS06, AN07], is a feature that allows users to associate words or phrases (“tags”) with the content they post, publish, or broadcast on the Internet. This functionality is extensively used to categorize and organize content, thus helping users to post/publish as well as searching and viewing content. In short: tagging, social networking, and the abundance of user generated content is the Internet state-of-art in the multimedia content realm.

Another relevant paradigm is the “any time, any place, any media” that is being fostered by the increase of available multimedia (e.g. IPTV[YXXDJZFHG07]) and inter-
personal communications (e.g., VoIP\cite{Goo02}, IM \cite{BNB00}). In this context the presence concept can act as a mechanism for several entities in the same domain to be aware of each others current status. This status information can express connectivity (online/offline), location and context, activity or other types of application-specific information.

Internet based applications are becoming richer in terms of media content, having several formats and different media profiles. On the other hand, access terminals are becoming increasingly sophisticated and powerful. When considered together, albeit problems related with heterogeneity may arise, these characteristics can also be the enabling factor in order provide the much desired seamless access to multimedia content.

In order to achieve this desired scenario not only an access infrastructure must be available but also the appropriate tools for the automatic selection and adaptation of content based on user’s and content presence information.

1.2 Motivation

The chief problem that is tackled in this thesis is thus: how to locate/consume content that is highly dynamic and at the same time take into account terminal and network heterogeneity.

The universal multimedia access (UMA) \cite{PvBA03} promises an integration of these different perspectives into a new class of content adaptive applications that could allow users to access multimedia content without concerning with specific coding formats, terminal capabilities, or network conditions.

The view adopted is this thesis is that these new paradigms (blurring between producers/consumers of content, content dynamics, and heterogeneity of terminals and networks) do not represent independent trends, but rather that there is an emergent class of complex services/applications that can explore these paradigms and are based simultaneously on:

- content availability;
- content description;
- end-user context (e.g., expressed as presence attributes);
- end-user profile (i.e., preferences, interests);

The above mentioned application scenarios typically require for their provision that a complete view of the entire multimedia chain (e.g., creation, production, distribution, consumption, modification), is adopted as proposed by the MPEG-21 Multimedia Framework \cite{JBP03}. In this framework two important aspects are patent:

- its user-centric view;
• the provision of the framework functionality by the cooperation and interaction between terminals and networks.

This latter aspect is also the chief characteristic of a novel type of networks known as Content Networks (CN). Content Networks distinguish themselves from Content Delivery Networks (CDN) by the fact that their participation in the multimedia chain goes beyond content distribution as they actively contribute to the management, creation, distribution, and consumption of content [TP06]. The following use case scenario highlights these characteristics.

A user, Rita, is registered in a Content Network and in her profile are declared both her interest in a particular type of audiovisual content, say football matches; and her friends list. When Rita is on-line at home using her Set-Top-Box, a content provider, SoccerTV, starts broadcasting a Manchester United match. By matching the user’s interest and content descriptions this event is announced to all the users in the CN, including Rita, that have an interest on this type of event. As a result of this announcement Rita decides to switch-on to SoccerTV broadcast. When a member of Rita’s buddy list, Bill, goes on-line (e.g., on his 3G phone), the CN notifies him that Rita in on-line and suggests a transcoded version of the same event. Bill decides to watch the match and start a voice conversation with Rita about the football match at hand. All their on-line friends sharing the same interest are then notified by the CN of this conversation that they join and thus “collectively watch” and comment the match.

This scenario, with its set of interactions involving users and content, can easily generate an enormous amount of signaling (e.g., announcing the content availability) and media flows. These flows represent a large and wide cloud that if unmanaged will be very hard to structure and/or aggregate, thus impairing the discovery and access to content. This situation can be particularly critical when dealing with the long tail phenomena [CKR+07] that characterizes the current trend in multimedia content posting/publishing on the Internet.

One technology family that is currently considered to deal with content distribution/access on the Internet is Peer-to-peer (P2P) content distribution technologies that mainly focuses on non-functional characteristics such as: security, scalability, performance, fairness, and resource management [ATS04]. In terms of infrastructure functionality are found: request-routing mechanisms, content replication techniques, load balancing, and cache management [PB07]. Although under the same technology classification, different design approaches are proposed for different contexts in order to respond to specific requirements. Therefore there is no single P2P technology that can meet the full set of features that this new multimedia content services/applications require for their deployment.

In order to address this problem the previously mentioned Content Network concept has emerged as a suitable solution, Kung et al [KW02] defines Content Network as an
overlay IP network that supports content routing. That is, in these networks messages are routed based on their content rather than the IP address of their destination. Permanent binding of content to hosts is no longer necessary to provide access to it. Nodes of the overlay network, called network or content nodes, route messages and may also store content. By using an overlay network, content networks have the flexibility to customize their topologies to meet specific application needs and performance objectives.

The motivation for this thesis is found mainly in the vision that albeit the current availability of technologies for the provision of individual/elementary features of these Content Networks (e.g., content distribution and description, user presence and profiling) there is still a need for an architecture where complex services, based on these elementary technologies, can be easily created and deployed. Moreover, Content Networks can play an important role on the generation of new services based on the “any time, any place, any media” paradigm and one of the most relevant example of social networks, or community-driven services.

CN can also contribute to improving content availability by reducing its access time and supporting content source independence. Due to the fact that in the CN content routing depends on the content description, a CN may provide the most appropriate content for user’s requests.

1.3 Objectives

In the current chapter the scenario and context of this thesis has been layed. This thesis aims at contributing to the realization of the previous scenario based on the CN concept, namely by providing an infrastructure where the following features are present:

- The management, distribution and consumption of content by announcing the presence of both content and users. The CN contributes actively to the creation of peer communities that are self-organized and formed implicitly due to the declared interests of human users and their context (e.g., location, friends list).

- Adaptation of content to user’s context (e.g., by selecting an appropriate format for each interaction).

- The creation of new content, thus supporting the tendency towards higher interconnectivity among peers from a certain region or sharing common interests [KSZ03], [MKD03]. The voice conference that is established between Rita and Bill and that their friends can join is an example of this types of live content.

In its remainder, this thesis aims to aid in the deployment of services provided by Content Networks with the following main contributions:
- The definition of a conceptual framework for Content Networks. In this framework are identified the elementary features for the provision of services in Content Networks as well as their associated tools and standards. (In Chapter 2).

- The definition of a layered architecture based on open standards and technologies in order to schematize a possible solution for a Content Network, having into account in the design criteria that it must be generic enough to enabling other conceptual and architectural elements to be added to it. (In Chapter 3).

- The system design, which includes system components and the working processes of main components. (In Chapter 4).

- An implementation of the proposed architecture and its evaluation in term of its functionality and performance. Performance is assessed by measuring different objective parameters (e.g., query match and delay) (In Chapter 5).

- The identification of some issues and possible paths for future research (In Chapter 6).
Chapter 2

Requirements and Use Cases

This chapter describes the starting point for the design of the CN platform in terms of its conceptual framework and requirements. The platform functional requirements are also presented here as a set of use cases.

2.1 Requirements

As mentioned in Chapter 1 the new telecommunications services/applications are becoming richer in terms of their multimedia content, blurring the boundaries between voice, video and data. They also offer the possibility to access any content, from any device, whenever and wherever users may desire.

Another important characteristic present in these new services/applications is presence information that when used with contextual information can provide advantages within a domain, for example, a user’s presence information may [Ros06] include his availability and willingness for communication, or in the case of distributed systems [JWS04] describe its resources status or its physical environment description.

Although there are many technologies available which provide these elementary features a framework is still required to further enable users access to any content with any device having also the awareness presence capability. The combined usage of these tools may provide a more efficient and effective resource location and consumption.

The main requirement for the platform for deployment of Content Networks is that it can ease the development and deployment of novel multimedia services through the seamless integration of elementary tools (e.g., multimedia signalling, presence, multimedia descriptions).

The conceptual framework and architecture that are proposed in this thesis are based on the fact that the above mentioned tools (e.g., presence, content descriptions) have commonalities that can and should be explored in the design and deployment of Content Network services as illustrated in Figure 2.1.
The declaration of user interests and terminal audiovisual capability descriptions should use common tools and open standard formats. In fact these tools are already available from different standard fora and with different complexity and capabilities.

In addition to this, users’ presence descriptions should be enriched using audiovisual capability metadata descriptions in order to declare her/his preferences as well as their status in terms of content usage (e.g., watching and chatting about the Manchester United match, using a 3G phone device). This capability is central for the creation and self-organization of peer communities based on audiovisual content interests and context.

The central concept used here is presence, as it should be applied to users and content alike. This last aspect, the presence of content, is chief in this thesis as the availability and characteristics (e.g., location, format) of audiovisual content should be announced to and queried by users and/or other content providers, creators, aggregators using presence tools. This is particularly needed in the case of content which is highly dynamic in terms of its availability and location as suggested by the “any time, any place, any media” and Web 2.0 paradigms. Presence services act thus as a mechanism for several entities (either users or content) in the same domain to be aware of each others’ status, be it: online/offline, location, context, activity or other application-specific information.

In summary, for the deployment of the information system that provides a new class of services for Content Networks described previously two chief tools are required: audiovisual content descriptions (i.e., media profile and related metadata) and presence information in the realms of content and interpersonal communications (i.e., location and format metadata) respectively. Meeting these requirements will allow:

- Matching users preferences and interests with available content;
- Building communities of users that share the same audiovisual content preferences/interests;
- The creation of new content based on already existing content;
- The customization and adaptation of content to context and its universal access.
In order to implement a platform that meets these requirements two approaches should be used simultaneously:

On one hand the communication sub-system should be viewed as a “service platform”, thus providing an abstraction layer from the delivery network and enabling the associated signaling for the development of applications and services (e.g., session setup, maintenance, closing).

On the other hand the information system, that is build mainly by multimedia content descriptions (namely media profile and metadata), should be used at the service provision level for providing a good balance of abstraction for the application knowledge within the communication sub-system.

That is to say, the communication sub-system should route signaling messages for this content (metadata) although not being aware of its semantic meaning a role played by the information system

### 2.1.1 Communication Sub-system

Until now Content Networks have rarely exploited the semantics of content to improve delivery. Kung et al. [KW02] describe a taxonomy for content networks and introduces a new class of content networks that perform “semantic aggregation and content sensitive placement”. Thus, content networks are classified based on their attributes in two dimensions: content aggregation and content placement.

The challenges in this context, as enumerated by Plagemann et al. [TP06] result mainly from how to find the right level of abstraction and balance the application knowledge within the communication sub-system.

In the case of CNs, the objective is not primarily to offer a better service than the common best effort service but rather to offer a consistent service throughout users sessions’ lifetime, namely, providing access to content at any time with any device, taking into account several characteristics such as network conditions, user’s terminal capabilities, available content resources, etc.

### 2.1.2 Information System

The information system supporting the multimedia services must be designed considering the different requirements, that arise from the task of sharing information from several sources: metadata descriptions (e.g., users preferences, available content) and contexts (e.g., users presence).

The different classes of requirements for the information system are associated with the support of:

- Multiple sources and views of metadata.

Namely, these different types and sources of metadata are:
Media Profile and related metadata refers to the type of multimedia data (e.g., video, audio, etc) and multimedia data formats. This type of metadata may enable the provision of optimized format for communication proposes for a specific multimedia delivery type (e.g., streaming) and terminal.

Another type of information used is location metadata, this provides information about where the "closest" source of the content can be found, this may refer to different formats and include various versions of the same content.

- Efficient and effective multimedia query and indexing.
  The semantic organization of metadata may increase multimedia content retrieval effectiveness and benefits user interaction for query or profile specification. The usage of semantic tools can be very useful for indexing, query specification, retrieval, filtering, user interfaces, and knowledge extraction from audiovisual material.

- Distribution of information within the network.
  Another issue that has to be addressed is if metadata can be placed closely with the content or may be managed independently. In previous multimedia systems specifications and standards the first was used (e.g., EPG in MPEG-2 or OCI in MPEG-4). In more recent standards (MPEG-7,-21) there is no need for a close linking between essence and metadata , thus increasing flexibility to keep metadata independent of the multimedia data.

2.2 Use Cases

The remainder of this section details the requirements for the CN platform using a set of use cases. The main functional requirements for the Content Network Information System are represented in Figure 2.2 using a UML Use Case Diagram.
The entities (UML actors) represented in Figure 2.2 are: *CN Application Server* that is a system that represents the Service/Application which implements the workflow functionality for the Content Network operation. The entity *Users* is a generalization from *End_Users* and *Content_Providers* because in Content Network context both users and content have the same domain, which is based on their presence information. It will be used the term CN users to refer to this latter entity.

The different use cases represented in Figure 2.2 are:

- **Publish Presence Info** - The functionality that enables CN users to publish their presence in the Content Network (e.g., a user interest, device used or new content format supported/available).

- **Discover Content** - The functionality where CN user receive notifications about a new available content or that another friend/client is now viewing a content that either it also provides or interested on.

- **Publish Content Info** - This functionality has two operations: the insertion of new content in the Content Network (e.g., a Content Provider broadcasting a live event) and the notification by the Content Network to end user about this new available resource.

- **Discover Users** - This functionality is available in the Content Network by the creation of CN users groups with similar interests (e.g., users that produce/consume content related to Football).

- **Consume Content** - This represents the process providing end to end media communication, this could be a new streaming session between a user 3G phone and a live stream from a Content Provider or it could be setting a VOIP call between two users.

- **Resource Location** - This function is the process within the Content Network which is responsible for searching, indexing, retrieving and organizing resources available (e.g., matching a CN user characteristic with another users offers).

- **Semantic Aggregation** - This process outlines the relationships between the several items (e.g, music names, user interests, video descriptions, etc) that are used to create the Multimedia Database provided by the CN information system.

- **Content Adaptation** - The functionality represents the capability that the Content Network has to adapt resources to a specific request (e.g., a CN user wishing to broadcast his videos to a set of friends with different terminal capabilities.)
- Abstract Access Device Heterogeneity - This function represents the Content Network capability to create an abstraction layer to the CN users that hides the network complexity and conditions, access terminal capabilities, etc.
Chapter 3

Enabling technologies

This chapter describes the existing technologies and related standards (mainly from the ISO/IEC MPEG and IETF fora) that provide elementary features and tools for the provision of Content Networks. In this context presence and audiovisual metadata descriptions are central concepts.

In section 3.1 it will be explained the features used from the ISO/IEC MPEG technology to handle the audiovisual metadata descriptions and CN semantic context aggregation.

The section 3.2 will describe the IP Multimedia Subsystem (IMS) [MW05], specified by the 3GPP forum, that aims at the convergence and integration between different networks by providing an abstraction layer associated signaling from the network/terminal heterogeneity and enabling the provision of applications and services.

The section 3.3 describes the several standards addressed by IETF namely in RFC 2778 [JDS00], RFC 3863 [Sug04], RFC 4479 [Ros06] and RFC 4480 [SJ06] that is used for users and content alike in the CN conceptual framework (described in the Chapter 2) presented in this thesis.

In section 3.4 it will be described Scribe [MCR02], a large-scale event notification infrastructure built on top of Pastry [RD01] a generic peer-to-peer (P2P) object location and routing infrastructure overlaid on top of Internet nodes, used in the CN to creation and self-organization of peer communities based on audiovisual content related interests and context.

Finally section 3.5 represents how an domain specific ontology is used to guide the definition of the entity instances of metadata and allows a more precise resource location.

3.1 Multimedia framework (ISO/IEC MPEG-21)

The Moving Picture Experts Group (MPEG) [MPE08] goal is to develop standards for the coded representation of moving pictures, audio and their combination. It operates in
the framework of ISO/IEC, and was responsible for the the MPEG-1 [Bra94] and MPEG-
2 [Has98] standards used in the core technologies behind digital TV, MP3s players and
DVDs.

The MPEG-4 standard [FCNP02] is being used mainly in Internet video content, and
more recently MPEG-4 part 10 (AVC) [Tam03] for mobile content and broadcasting areas.
In turn the MPEG-7 standard [PS01] was defined for the description of multimedia content
using XML metadata. The latter promises interoperability in search and retrieval.

However, due to the lack of content, inability to secure rights, the proliferation of
multiple and unrelated content formats and terminal types. Overall this confusing array
of technologies was the driving force for MPEG-21 standard [ISBK06] as it was found
that many elements exist to build an infrastructure for the delivery and consumption of
multimedia content, but there was no "big picture" to describe how these elements relate
to each other.

MPEG-21 was a solution that would offer users transparent and interoperable con-
sumption and delivery of rich multimedia content. The aim was to create a standard that
would link together the media coding and metadata standards with access technologies,
rights and protection mechanisms, adaptation technology, and standardized reporting so
as to produce a complete "multimedia framework”.

3.1.1 MPEG-21 vision and components

The vision for MPEG-21 was thus to define an open multimedia framework [JBP03] that
would enable the transparent and augmented use of multimedia resources across a wide
range of networks and devices used by different communities. The intent was that this
framework will cover the entire multimedia content delivery chain encompassing: content
creation, production, delivery, personalization, consumption, presentation, and trade.

The MPEG-21 standard has two main concepts [ISBK06] that are very important for
meeting the CN requirements:

- The definition of a fundamental unit of distribution and transaction called Digital
  Item (DI), considered the "what" of the multimedia framework (e.g., video, music,
  image);

- The concept of users interacting with digital items, considered the "who”, as identi-
  fied in the CN requirements (Chapter 2). MPEG-21 does not differentiate between
  a ‘content provider’ and ‘consumer’ – both of them are Users and interact with Di-
  gital Items. Users assume certain rights and responsibilities depending on the type
  of interaction they have with other Users and particular Digital Items.

Additionally MPEG-21 technology should be adopted in the CN design and deployment
because in this framework two important aspects are patent:
• Its user-centric view;

• The provision of the framework functionality by the cooperation and interaction between terminals and network nodes.

The MPEG-21 vision of "the overall picture" divided the multimedia framework into seven loosely grouped architectural elements [JBP03]. From this set Digital Item Declaration (DID) [BKdS06] and Digital Item Adaption (DIA) [VT05] are the most relevant elements for the provision of the CN core functionalities.

DID introduces a set of abstract terms and concepts to form a model for defining DIs. In addition, the DID contains the description of the syntax and semantics of each of the DID elements and the DID Schema for its representation in XML. DIA specifies metadata for assisting the adaptation of Digital Items according to constraints on the storage, transmission and consumption, thereby enabling various types of quality of service management. Figure 3.1 shows these two elements within the MPEG-21 multimedia framework vision.

![MPEG-21 Vision and Architectural Components](ISBK06)

**MPEG-21 DID**

The DID technology [ISBK06] defines a clear model for the definition of a Digital Item (DI), providing a set of abstract concepts and terms that can be used to define a scheme for it. It is described in three normative sections:
- **Model**: Describes a set of abstract terms and concepts for defining DIs. Within this model, a DI is the digital representation of, for example, a video collection.

- **Representation**: An XML normative description of the syntax and semantics of each of the Digital Item Declaration elements.

- **Schema**: Normative XML schema comprising the entire grammar of the Digital Item Declaration representation in XML.

Figure 3.2 is an example showing the most important elements of the DID technology, how they are related, and as such, the hierarchical structure of the Digital Item Declaration Model.

![Figure 3.2: MPEG-21 DID Model](image)

A container is a structure that allows items or other containers to be grouped. These groupings of items or containers can be used for example in the organization and transport of DIs. The container definition is recursive and, therefore, may be used to form hierarchies. For instance, if several videos are grouped in a DI, then a container having an item declaration for each video can be used as shown in Figure 3.3.
An item is a grouping of subitems or components that are bound to relevant descriptors. Descriptors contain information about the item, and may contain choices, which allow them to be configured. Items may be conditional on predicates asserted by selections defined in the choices (e.g., media format). Items may contain subitems if they are composed of potential subparts. Items may also contain annotations (i.e., media descriptions) for their subparts.

The main components, which appear in the declaration of an item, are the component and the descriptor. Their relationship is illustrated in Figure 3.2.

A component is the binding of a resource to all of its relevant descriptors. The component’s descriptors are metadata related to all or parts of the specific resource instance. Such descriptors will typically contain control or structural information about the resource (e.g., bit rate, compression). A component may also contain conditions to describe optional resources and descriptors. Conditions are used in connection with choice and selection elements declared in the same DI. Finally, the component may contain an anchor. It binds a set of descriptors to a specific location within the resource. For instance, Figure 3.4 illustrates a component description fragment of a DID that contains an anchor description for a complete mpeg4 video file and an anchor for the first 30 minutes of the same video.
The relevance of DID concepts and tools in the provision of CN is found in the fact of it creates an abstraction layer, that simplifies the way how the information is used for the audiovisual material descriptions, namely its pairing with requests and its adaptation to particular contexts (e.g., terminal capabilities).

**MPEG-21 DIA**

The goal of the terminals and networks key element [ISBK06] is to achieve interoperable transparent access to distributed advanced multimedia content by shielding users from network and terminal installation, management and implementation issues. This will enable the provision of network and terminal resources on demand to form user communities where multimedia content can be created and shared. One of the main aims of this key element is to provide services always with the agreed/contracted quality, reliability and flexibility, allowing multimedia applications to connect diverse sets of users, such that the quality of the user experience will be guaranteed.

This architectural element from the MPEG-21 multimedia framework aims to provide end-to-end interoperability and is a key factor to the CN elementary features. That is, it offers a framework to build an infrastructure for the delivery and consumption of multimedia content as defined in MPEG-21 Part 7 - Digital Item Adaptation.

Towards this goal the adaptation of DI is required, and this mechanism is available through MPEG-21 Part 7 - Digital Item Adaptation Tools [Vet04]. This concept is illustrated in Figure 3.5. As shown in this conceptual architecture, a DI may be subject to a resource adaptation engine, as well as a descriptor (or metadata) adaptation engine, producing the adapted DI.

Figure 3.4: MPEG-21 DID Components
It is important to emphasize that the adaptation engines themselves are non-normative tools, however, descriptions and format-independent mechanisms that provide support for Digital Item Adaptation in terms of resource adaptation, descriptor adaptation, and/or Quality of Service management are within the scope of the standard.

The terminal capabilities as well as characteristics of the network, user, and natural environment are variables that play a very important role in this process.

In terms of terminal capabilities the following classes of description tools are identified:

- Codec capabilities, this corresponds to the encoding or decoding capability (e.g., AVI);
- Input-output capabilities, this corresponds for example to the display size;
- Device properties, related for example to device storage capacity;

Other variables are the Network characteristics in terms of:

- Network capabilities, (e.g., the available bandwidth);
- Network conditions, (e.g., its delay characteristics);

User characteristics may be described by the following aspects:

- User info, usage preferences, and content usage history, mapped from the MPEG-7 MDS (explained in Section 3.1.2);
- Presentation preferences, this could be for example the color settings for audiovisual material;
- Accessibility characteristics, used to adapt content according to certain auditory or visual impairments;
- Location characteristics, related to description his mobility;

Finally the natural environment characteristics specified by:

- Location and time, related to the MPEG-7 MDS (explained in Section 3.1.2);
- Audiovisual environment, this could be related to for example the sound level of an outside event
3.1.2 MPEG-7

As already mentioned a DI can be anything from an elemental piece of content (e.g., picture, video) to a complete collection of audiovisual material. As the DI is only a container, it requires that its description is filled using existing metadata standards, to facilitate their integration in the whole distributed multimedia system. In the XML document shown in Figure 3.3 declaring a DI, the Descriptor contains the DI related metadata in the form of a statement. Alternatively, a component element containing descriptive multimedia data can be used (for example, an image containing a set of thumbnails showing the time/location of each video).

The statement is a flexible description tool that may contain any data format, including plaintext and machine-interpretable formats, for example, XML, identified by a MIME media type as defined in RFC 2045 [NB96]. The used MIME media type is given in the attribute mimeType. In the example provided in the top of Figure 3.3 the plaintext (mimeType = "text/plain") description "My Vacations in LA" is used, however, it is semantically poor as it has no structure. One may rely on MPEG-7 Description Schemes [ISO03] for a more richer and structured description, as illustrated in Figure 3.6.
The MPEG-7 standard provides tools allowing the description of audiovisual (AV) data content in multimedia environments. Audiovisual data content that has MPEG-7 metadata associated with it may include still pictures, graphics, three-dimensional models, audio, speech, video. Moreover, it enables the description of composition information about how these elements are combined in a multimedia presentation scenarios. Additionally it also provides different granularity in its descriptions, offering the possibility of having different levels of discrimination and detail.

The main elements of the MPEG-7 standard are (see Figure 3.7):

- Description tools: Descriptors (Ds) that define the syntax and the semantics of each feature (metadata element); and description schemes (DSs) that specify the...
structure and semantics of the relationships between their components that may be both descriptors and description schemes.

- Classification Schema (CS): Defines a list of typical terms used in many applications together with their meanings. For instance, it allows the definition of file formats in a standardized way. MPEG-7 provides many predefined CSs for characterizing roles, formats, and so forth.

- DDL: Defines the syntax of the MPEG-7 description tools and allows the creation of new description schemes and descriptors, and the extension and modification of existing description schemes.

- System tools: Support binary coded representation for efficient storage and transmission and provide the necessary transmission mechanisms.

MPEG-7 addresses many different applications in many different environments, which means that it needs to provide a flexible and extensible framework for describing AV data. Therefore, MPEG-7 does not define a monolithic system for content description but rather a set of methods and tools for the different viewpoints of the description of AV content. Another MPEG-7 characteristic is that metadata may be physically located with the associated AV material, in the same data stream or on the same multimedia database system, but the descriptions can also live somewhere else. MPEG-7 tools, notably MDS tools, are used in the proposed CN architecture for:

- describing content in terms of its material (e.g., location, coding format, resolution) and semantics (e.g., scenes descriptions in terms of its attributes);
describing user preferences, interests and usage context (e.g., event type, terminal capabilities);

Another important feature from MPEG-7 in the CN context is the fact that it allows extensibility of description tools used by the CN (e.g., audiovisual metadata, user preferences), in terms of semantic indexing and filtering, providing a semantically personalized services. The semantic personalization is built on top of semantic user preferences and media descriptions, which are used as content-related context during both indexing (where the user preferences will be used in order to expand and/or disambiguate the user interests) and filtering (where the user preferences will be used to select appropriate content).

Tsinaraki et al [CTC05] state, that domain knowledge, in the form of domain ontologies, can be expressed using MPEG-7 constructs and integrated in MPEG-7 semantic descriptions. The rich information captured in the MPEG-7 descriptions allows providing powerful retrieval and filtering capabilities on top of them.

3.2 IP Multimedia Subsystem (IMS)

Another very important and critical service in the CN context is the connectivity capability. This feature allow a user in the CN to connect to everything (or almost) in today’s global system, the Internet. It is based on this capability that the IP Multimedia Subsystem (IMS) introduces [KS06] multimedia session control in the packet-switched domain and at the same time brings circuit-switched functionality into this. In other words is it an architecture for the convergence of communications, data/voice in fixed and mobile networks. IMS is based on set of protocols and provides an abstraction layer and associated signaling for the development of applications and services.

The advent of the IMS specified by 3GPP as the most promising candidate for replacing legacy mobile and fixed networks towards an All-IP infrastructure and thus putting “Next Generation Network” into reality has raised considerable interest both in industry and academia. In contrast to traditional IP networks, IMS guarantees end-to-end Quality of Service (QoS) in the network and creates an infrastructure that allows to quickly deploy novel services as well as flexible billing, whereas compatibility with existing applications is still maintained. Moreover, the horizontal service architecture defined in IMS is responsible for different functions that can be roughly classified in tree layers shown in Figure 3.8.
3.2.1 Service Layer

This layer implements features such as call control, user interaction, user status, data session control, terminal capabilities, account management, etc. The components at this layer, AS (Application Server), provide SIP-based services and value-added multimedia services, such as presence, push to talk over cellular, etc.

The Service Layer is populated by Application Servers (AS) providing two different types of functions:

- User Applications - providing services functionality to end users;
- Service Enablers - providing functionality for third party services (a notable example is presence);

3.2.2 Control Layer

The Control Layer is the core of the IMS architecture, the Session Management and Routing functionalities provided by the elements in this layer act during registration, session establishment and routing, and are divided in several components:

- P-CSCF (Proxy Call Session Control Functions) is the first contact point for users within the IMS, meaning that it will route all signalling traffic from the UE (user equipment) to the network and vice-versa.
- S-CSCF (Serving Call Session Control Functions) is the focal point of the IMS as it is responsible for handling the registration process, making routing decisions, maintaining session states and storing the service profile (for example, it is at the S-CSCF that services are triggered).
• I-CSCF (Interrogating Call Session Control Functions) is a contact point within an operator’s network for all connections destined to subscribers within that network domain.

• MRFC (Multimedia Resource Function Controller) its task is to handle protocol communication, i.e. SIP, in order to provide mechanisms for bearer-related services such as conferencing, video streaming, voice.

• MRFP (Multimedia Resource Function Processor) provides user-plane resources that are requested by the MRFC such as stream processing, transcoding, etc.

Additionaly there are also databases that are used for storing information about the IMS infrastructure and its users. These are divided in two main components:

• HSS (Home Subscriber Server) is the main data storage for all subscribers and service-related data of the IMS, (e.g., user identities, registration information, access parameters and service-triggering).

• SLF (Subscription Location Function) is used as resolution mechanism that enables I-CSCF, S-CSCF to find the address of the HSS that holds the subscriber data for a given user identity.

3.2.3 Transport Layer

This layer is an abstraction of the interworking functionality that is responsible for exchanging signalling and media between IMS networks and/or the circuit-switched network. This internetworking functionality is provided mainly by two components:

• BGCF (Breakout Gateway Control Function) receives SIP session to breakout to the CS domain.

• MGCF (Media Gateway Control Function) performs protocol conversion between SIP and ISDN User Part.

When there is a need for a breakout between the PS and CS network the behavior is different if this happens in the same operator network (where it uses MGCF) or with a different operator (BGCF).

Other components of the transport layer that can be useful for the CN as a commercial offer are related with authorization and the provision of QoS, namely:
• PDF (Policy Decision Function) is responsible for making policy decisions based on session and media related information obtained from P-CSCF. This is the chief component for the provision of QoS features.

• SEG (Security Gateway) has the function of protecting control-plane traffic between security domains.

• THIG (Topology Hiding Inter-network Gateway) it is a functionality that can be used to hide the configuration, capacity and topology of a network from outside the operator’s network.

### 3.2.4 IMS protocols

The main aim of IMS is to provide value added IP Services in existing technologies, using standard and well established protocols. These can be classified in three broad categories:

• Signalling or session control. For this purpose the Session Initiation Protocol (SIP) [JRS02] was adopted. SIP is an application-layer protocol, endorsed by IETF, responsible for establishing, modifying and terminating multimedia sessions with one or more participants. These sessions can be multimedia conferences, instant messaging, Internet telephone calls or other similar applications between two or more participants.

• Media Plane. Although media delivery is out of IMS scope, RTP and RTCP are widely adopted protocols, both defined in RFC 3550 [HSJ03]. RTP transports real time media such as audio and video using UDP for its transport. This protocol is mostly useful when used in combination with RTCP which provides statistics and information about the media stream (delay jitter, loss rate).

• Security. For the several IMS components to communicate with each other in a secure way it is used DIAMETER [PC03] an improved version of an earlier authentication protocol called RADIUS [CRS00].

### 3.2.5 IMS usage in the CN context

As defined in the previous sections IMS is not a service in itself; but rather a SIP-based architecture for enabling advanced IP services and applications on top of the PS and CS networks. IMS provides the necessary tools for invoking services; this functionality is called ”service provision”, and it is in this context that CN, (as described in this thesis) may abstract its networking infrastructure setup in terms of message delivery and
configuration by relying this tasks to the IMS infrastructure. IMS service provisioning contains three fundamental steps:

- Define possible service or service sets.
- Create user-specific service data in the format of Initial Filter Criteria when a user orders/modifies a subscription.
- Pass an incoming initial request to an application server (this corresponds to triggering the service).

The first item is not comprehensively addressed in the core of this thesis because it is up to the operators and service providers to define what kind of services they are willing to offer their subscribers. Although not in the core of this thesis, an illustrative example on how to provision a service can be found in Chapter 5 where a use scenario demo is described.

The other two steps are:

- Defining the service related configuration parameters (shown in detail in Chapter 5) in order to provide the service (e.g., SIP Header Event: presence.cninfo);
- Receiving SIP messages from the IMS infrastructure and redirecting them to the appropriate AS (shown in detail in Chapter 5);

Whenever a user obtains an IMS subscription and her subscription contains some value-added services (e.g., a voice mail) or an operator is willing to use ASs as part of its IMS infrastructure, they need to create service-specific data for that user. These service-specific data are part of the user’s user profile and stored in the HSS. More precisely, service-specific data are represented as Initial Filter Criteria. When constructing an Initial Filter Criteria an operator needs to consider these questions:

- What is the Trigger Point that "starts" the service?
- How do requests arrive to a specific AS when the Trigger Point is fired?

The Trigger Point is used to decide whether an application server is contacted or not. It contains one or multiple instances of a Service Point Trigger [3GPP TS 29.228]. The Service Point Trigger comprises the items shown in Figure 3.9.

![Service Point Trigger](image)

Figure 3.9: IMS - Service Point Trigger
- Request-URI—identifies a resource that the request is addressed to (e.g., sport-news@ims.example.com).

- SIP Method—indicates the type of request (e.g., INVITE or MESSAGE).

- SIP header—contains information related to the request. A Service Point Trigger can be based on the presence or absence of a SIP header or the content of any SIP header. The value of the content is a string that is interpreted as a regular expression. A regular expression could be as simple as a proper noun (e.g., the value in FROM header that indicates the initiator of the request).

- Session Case—has three possible values, Originating, Terminating or Terminating Unregistered, that indicate whether the filter should be used by the S-CSCF that is handling the originating, terminating or terminating for an unregistered end user services. An originating case refers to when the S-CSCF is serving the calling user. A terminating case refers to when the S-CSCF is serving the called user.

- Session Description—defines a Service Point Trigger for the content of any SDP field within the body of a SIP method. Regular expressions can be used to match the trigger.

Initial Filter Criteria are downloaded from the HSS to the S-CSCF at user registration or at a terminating initial request for an unregistered user. After downloading the user profile, the S-CSCF assesses the filter criteria for the initial request [3GPP TS 24.229].

If a SIP message that arrives at the S-CSCF meets the IFC and some other criteria (e.g., originating or terminating session) then the trigger is fired, this event typically involves sending the SIP message to an AS (shown in detail in Chapter 5).

In Figure 3.10 are shown several examples of Initial Filter Criteria.

<table>
<thead>
<tr>
<th>Element of Filter Criteria</th>
<th>Filter Criteria 1</th>
<th>Filter Criteria 2</th>
<th>Filter Criteria 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPT: Session Case</td>
<td>Originating</td>
<td>Originating</td>
<td>Terminating</td>
</tr>
<tr>
<td>SPT: Public user identity</td>
<td>sipuser1@ims</td>
<td>sipuser1@ims</td>
<td>sipuser1@ims</td>
</tr>
<tr>
<td>SIP Method</td>
<td>PUBLISH</td>
<td>SUBSCRIBE</td>
<td>INVITE</td>
</tr>
<tr>
<td>Application Server</td>
<td>sipias1.liscte.pt</td>
<td>sipias2.liscte.pt</td>
<td>sipias3.liscte.pt</td>
</tr>
</tbody>
</table>

Figure 3.10: IMS Initial Filter Criteria

### 3.3 Presence Services

Another implicit characteristic in today’s Internet applications in the “any time, any place, any media” paradigm is presence. Presence services act as a mechanism for several entities in the same domain to be aware of each others current status (e.g., online/offline, location, contextual, activity or application-specific information). According to [HS06]
presence may be the dial tone of the twenty-first century communication systems providing new communication capabilities such as:

- Replacing multiples contacts addresses, i.e. e-mail, business phone, home phone, etc, that the called party may have represented as a single icon.

- Avoiding futile non-answered calls that may end in voice mail.

- Enabling the most adequate form to contact someone (i.e., using IM instead of a voice call when the called party must be quiet in a meeting).

Presence information is used in the CN for both announcing users status and preferences as well as the available content and its descriptions. There are already several protocols and data formats for presence being the most used Instant Messaging and Presence Protocol (IMPP) \cite{MDV00} and Extensible Messaging and Presence Protocol (XMPP) \cite{SA04}. However, a large number of proprietary IM services have emerged on the Internet with no interoperability bringing problems for users that have to keep several IM applications running on their terminals. In order to solve this problem the IETF Instant Messaging and Presence Protocol Working Group was created to develop an open standard, interoperable, and scalable protocol. The result was a document (Common Presence and Instant Messaging (CPIM) \cite{Pet04}) that allows internal protocols and data formats of various IM systems to be local business decisions, while interoperability between IM systems is possible via CPIM.

IETF defined also a model for presence \cite{JDS00}. This is meant to help understanding the presence concepts basics and is not a standard. The model defines two services: a presence service and an instant message service. Only the first is described here given that IM services are out of the scope of this thesis.

The Presence service purposed is bound to accept presence information store it, and distribute it. This service has two sets of “clients”; presentities (that store and distribute presence information) and watchers (receive presence information from the service), see Figure 3.11. A Presence service is viewed an abstraction that communicates with the

![Figure 3.11: Presence Model](image)
presentity and watcher using the SIMPLE [JRG02](stands for SIP for IM and Presence Leveraging Extensions) presence protocol. The presentity information is usually displayed to the watcher on the UA as a “buddy” or “contact”. A watcher usually has a buddy list and one can see their status at a glance.

The Presence Information Data Format (PIDF) [Sug04] standard has great flexibility due to using XML for representing presence information as series of tuples. The Presence Data Model (PDM) [Ros06] acts as a guidance on exactly what a tuple is meant to model, or how to map real-world communications systems into a presence document, as shown in Figure 3.12.

![Figure 3.12: Presence Data Model](image)

The PDM is therefore a key tool for semantic interoperability as it is used in the CN context, as it allowed to integrate in a transparent way other tools used (i.e., MPEG-7-21 for audiovisual content metadata) in the CN.

The PDM defines three important concepts, (that were not clearly modeled by the previous RFCs 2778 and 3863), namely:

- **Service**: A communications service, such as instant messaging or telephony. That is, a service for the interaction between users that provides certain modalities or content (e.g., voice call, IM).

- **Device**: A communications device is a physical component that a user interacts with in order to send or receive communication signalling and media (e.g., softphone, video terminal).

- **Person**: A person is the end user, and for the purposes of presence, is characterized by several states, such as “busy” or “online”. A user’s state reflects this ability and/or willingness to communicate.

In the CN case this status information is enhanced with users preferences in terms of media consumption and context and in the case of content provided with content descriptions. This usage of presence tools in the CN is due to a more comprehensive work on
the use of presence is reflected in the Rich Presence Extensions to the Presence Information Data Format (RPID) [SJ06]. The presence information data in RFC 3863 that is intended for humans has been extended to be generated by applications for consumption by automata’s, while maintaining backward compatibility with RFC 3863.

3.4 P2P Paradigm and tools

Peer-to-Peer (P2P) is not a completely new paradigm and in fact it has been somehow applied in the original Internet design, for example, in basic Internet routing or in applications such as Usenet News. Recently the success of applications based on the P2P concept has created a huge diversity of approaches.

In terms of design philosophies the most important is probably JXTA, a programming platform for P2P applications that defines a 3-layer architecture (kernel, services, application). Dabek et al. [FDS03] proposed a common API (c programming interface level) for structured overlays networks and Aberer et al. [KA05] proposed a reference model intended to support the assessment of P2P system properties.

Although different types of architectures have appeared there are mainly three different architectures that can be identified in P2P systems:

- Centralized: where central index servers are used to maintain a directory of shared content stored on peers. In this architecture a peer can search for the location of desired content from an index server. A well known example of this type of architecture is Napster [SSG03].

- Decentralized structured: where the shared data placement and topology characteristics of the network are tightly controlled based on keys that are produced and stored using a distributed hash table (DHT). There is one basic operation in these systems, look up (key), which returns the identity (e.g., the IP address) of the node storing the object with that key. The DHT nodes form an overlay network with each node having several other nodes as neighbors. When a lookup (key) is issued, the lookup is routed through the overlay network to the node responsible for that key as represented in Figure 3.13. Examples of implementations are: Chord [ISB01], Pastry [RD01] and CAN [SRS01].

- Decentralized unstructured: where data placement has no correlation with the network topology. In this architecture search is performed by “flooding” queries until the query is met. The most known implementations are KaZaA [JLR05] and Gnutella [SSG03].
Although this wide variety of solutions, Milojicic et al. [DM03] have identified that the P2P model should satisfy the following three criteria:

- **Self-organizing**: nodes organize themselves into a network through a discovery process.
- **Symmetric communication**: peers are considered equals; they can both request and offer services, rather than being confined to either client or server roles.
- **Decentralized control**: peers determine their level of participation and their course of action autonomously.

These criteria are key factors in highly distributed systems such as CNs. Additionally, another common characteristic is that a P2P network must always provide several infrastructure services that should also be present in CN, namely:

- **Publishing**: To share a resource, a peer must publish it and enable it to be accessed by other peers.
- **Resource location**: Before consuming a resource, a peer must locate it on the network.
- **Resource consumption**: Once the resource has been located, it must be invoked for use. This requires standard protocols and formats for accessing resources.
- **Usage services**: Invocation of a resource may require certain services such as: security management (authentication, non repudiation, confidentiality), transactional unity, availability (by failure recovery), and performance (by balancing loads across different peers).

Taking into consideration all of the above mentioned characteristics, a CN service enabler can efficiently use Scribe [MCR02], a large-scale event notification infrastructure that
was designed for the support of topic-based publish-subscribe applications. Scribe is built on top of Pastry [RD01] a generic peer-to-peer (P2P) object location and routing infrastructure overlaid on top of Internet nodes.

Scribe not only guarantees support for large number of topics (subscription groups) with a potentially large number of subscribers per topic; but also implements persistence of topic subscriptions. Additionally it builds efficient multicast trees associated with these topics. Scribe’s randomized placement of topics and multicast roots balances the load between participating nodes. Another advantage of this publish/subscribe paradigm is that publishers and subscribers are loosely coupled in time, space and flow [PTEK03], which is a key factor for large-scale and highly dynamic distributed systems.

Furthermore, Pastry’s properties enable Scribe to exploit locality to build efficient multicast trees and to handle subscriptions in a decentralized manner. However, for the proposed CN architecture, Scribe’s most important characteristic is its multicast facility that is used to discover and manage large quantities of resources based on topics.

For example, a topic can be created due to the availability of a new content resource (e.g., a highly dynamic resource such as a multimedia teleconference, a VoIP call, a video stream, an audio broadcast).

A major contribution of the proposed CN architecture is that topics, and the associated multicast overlay, are created using content metadata description. A node providing a resource joins this topic multicast overlay in order to advertise its availability, this is accomplished by the content in Scribe messages structure. Other nodes (e.g., users or other content aggregators) interested in content with similar descriptions joint the same multicast overlay and their interest is distributed to all its members, including the node where this resource is available.

### 3.5 Ontology concept and tools

As already mentioned in Section 3.1.2 semantic interoperation is achieved through domain knowledge, which can be expressed in the form of domain ontologies. This domain knowledge is subsequently used for supporting semantic retrieval and filtering [TC06] where it has shown to enhance the retrieval accuracy [CTC07].

The CN domain-specific ontology, as specified in [CTC05], provides semantic constructs for the description of both Application-Specific Metadata and Instance-Description Metadata. Thus, the content and structure of CN domain-specific ontology are stored in the Semantic Base as the Stored Ontology shown in Figure 3.14.
MPEG-7 MDS also provides the definition of semantic entities. The CN uses this definition via the *SemanticBaseType* attribute (and thus inherited in all its extensions) to organize the CN semantic indexing. The attribute *Type* is used by the CN as a namespace in order to select the appropriate semantic base class (e.g., PersonType, OrganizationType).

The main purpose of a CN ontology is to guide the matching of entity instances (e.g., Cristiano Ronaldo has the same meaning as Manchester Player number 7). By using these more refined terms as Scribe topic-keys allows a more precise and richer resource location process.

Figure 3.14: CN Ontology
Chapter 4

Design and Implementation

This chapter describes the design and implementation of a Content Network platform. The main aspects that are covered in each of its sections: the architecture for the CN (in Section 4.1) and how this can be seen as a service enabler, CN internal design and how information is handled (in Section 4.2), the class implementation (in Section 4.3), the CN services functional characteristics (in Section 4.4) and finally a use case of these functionalities (in Section 4.5).

4.1 Architecture

As identified in [TP06] the main challenge for the design and deployment of services in the novel Content Network is found in the heterogeneity resulting from two main sources:

- its terminals and access networks;

- the different elementary service/applications associated to the tools (e.g., presence, content management);

The approach adopted in this work is to tackle this problem by defining a layered architecture for Content Networks as represented in Figure 4.1.
The top layer is populated by the applications/services that end users interact with when using the CN services (e.g., finding, publishing or consuming content). The CN middleware layer provides a services enabler infrastructure that can be used by the upper layer elements for their interaction without a priori knowledge of the details (e.g., location) of each other and abstracting the characteristics of lower layers (e.g., control and transport layer).

At the lower layer of the Content Network architecture stack is found the Transport Layer. This layer is responsible for all the end-to-end communication and can be deployed by point-to-point (P-to-P) and/or point-to-multipoint (P-to-M) technologies; in fixed and/or mobile environments and using packet and/or circuit switching. Chief among the characteristics of this layer is its heterogeneity.

The Control and Media Layer is associated to both signaling and media management and delivery in the Content Network. This layer, if properly designed, can be also be used to hide the heterogeneity present in the Transport Layer in particular its signaling and media delivery protocols. As described in Chapter 3, the IP Multimedia Subsystem (IMS) [MW05], aims at this convergence and integration between different networks by providing an abstraction layer and associated signaling for the development of applications and services. Chief among the signaling protocols in IMS is the Session Initiation Protocol (SIP) as it is used at most of the IMS core reference points and between the IMS and applications servers. In the CN architecture SIP is used for the establishment, modification and termination of multimedia sessions and for generic messaging (e.g., presence information). Figure 4.2 illustrates the usage and integration of IMS in the proposed Content Network layered architecture.
The different tools that are required for the provision of Content Networks (user profiles, presence services, content management, metadata extraction, indexing and matching) are covered by Home SS (HSS), Presence Servers (PS), Content Servers (CS) and IMS Application Servers (in this particular case Content Network Application Servers - CNAS). All interactions (i.e., SIP messages) between the CNAS and the networks core elements occurs at the ISC reference point via the S-CSCF IMS core element. The IMS acts thus as an abstraction layer between the application elements and the network infrastructure hiding the heterogeneity of both terminal access and core networks.

Interactions between elementary Content Network Application Servers (i.e., P2P Scribe messages) are used to provide the complete complex services in the Content Network. For example, the main difficulties for supporting these interactions result from the heterogeneity associated with the specialization of each service (e.g, presence, content, etc) and the dynamics resulting from the interaction between users and between users and content.

Moreover, as the interconnection of generic Application Servers (AS) populating the Services Layer is not in the IMS specifications scope it cannot contribute directly to mitigate the problems associated to applications/tools heterogeneity. This role is thus played by the CNAS overlay that hides the complexity of these applications/tools functions in terms of searching, publishing, consuming, adapting, promoting user interaction in the Content Network.

4.2 CN internal design

As referred in [CKR+07] the large scale, dynamics and decentralization of the user generated content is the current state of multimedia in todays Internet. The CN represents thus a highly distributed information system, for the provision of content networks where users can interact with available content, based on the characteristics already mentioned (content descriptions, users preferences and presence). This infrastructure is deployed by an overlay network that is dynamically build as result of user and content presence and
their declared interests and descriptions.

The overlay should guarantee the correct publication, location and consumption of the resources in cause. Peer-to-peer (P2P) systems that have these characteristics [KA05][ATS04] will naturally, meet the requirements set for the overlay. The characteristics of most P2P systems are particularly suited for the implementation of the desired overlay networks as they usually provide: a multicast delivery infrastructure, resources discovery functionality; and can accommodate the node join/leave process. Figure 4.3 shows the internal design of one node instance that forms the overlay, with is divided in two major blocks:

- CNAS Instance - Responsible for the P2P overlay and multicast infrastructure and for the IMS integration and internal control interfaces (e.g., application workflow);
- CNAS Data Model - Represents the distributed information system and its operation, maintenance and structure (e.g., metadata handling).

![Figure 4.3: CN - Node instance design](image)

### 4.2.1 CNAS Instance

The CNAS Instance represents the application instance that is running as a CN node and is composed by: an underlying "customized" Pastry\(^1\) [RD01] node and a Presence Proxy. The Presence Proxy that acts has a watcher for presence information in terms of content presence and users subscriptions state information.

\(^1\)Pastry is a generic peer-to-peer object location and routing infrastructure overlay on top of Internet nodes, this makes available Scribe [MCR02], a large-scale event notification infrastructure that was designed for the support of topic-based publish-subscribe applications.
The customization of the Pastry node is mainly related with Pastry Socket API extension to receive messages from the IMS infrastructure at the ISC reference points on a transparent form (explained in detail later in the section 4.3). Finally, the CNAS Instance is also responsible for the application Workflow component, i.e., the core functionality of the CNAS middleware given that it is where the complexity abstraction of the several services is implemented (explained in detail in Section 4.3).

4.2.2 CNAS Data Model

The CNAS Data Model that is used for storing/indexing the user preferences and content descriptions is based on the structures of the Semantic DS defined in MPEG-7 Multimedia Description Schemes (MDS) [ISO03]. These powerful primitives are sufficient and well adapted for the description of complex real-world concepts and relationships found in the different CN domains. Notably they can be used for both domain ontology description and multimedia content description based on our domain specific ontology (described in Section 4.4.3).

The CNAS data model component is based on three main sub-components:

The uniform representation of ontology and semantics within MPEG-7 allows powerful retrieval support that can be used in many retrieval aspects (indexing, disambiguation, etc.), and greatly improves the expressiveness of the publish/subscribe system without the sacrifice of matching efficiency, this way the inadequacies of keyword-only descriptions are prevented. This functionality is implemented at the CN Ontology component.

Additionally a Metadata Parser component was implemented in order to guarantee the correct insertion of new information in the data model and for processing and validating the audiovisual metadata associated to the content and presence information.

Finally the UMA Profiler component is responsible for the media profile adaptation. The approach adopted is defined by MPEG-21 Digital Item Adaptation Architecture [ISBK06] and the MPEG-7 MDS for content and service personalization and adaptation.

This adaptation is based on user/content context, and related to user device capabilities, usage, natural environment and network characteristics.

4.3 CNAS class implementation

This section details the CNAS implementation in terms of CN services functional characteristics. Figure 4.4 shows a high level UML class diagram representing the class implementation of the CNAS most important functionalities.
4.3.1 CNAS instance class

The main classes identified for the CNAS instance component implementation are:

- **CNAS Instance** - This class represents the main component from the CN Application Server, is responsible for the initialization of several modules (e.g., workflow, Pastry/Scribe), it has a *PastryNodeId* attribute that represents the identifier of a Pastry node handle used to build the P2P overlay network.

- **Pastry** - This “customized” Pastry node provides a CN Scribe publish-subscribe infrastructure and forms the P2P overlay network. An API extension was implemented to the Pastry messages listener in order provide the functionality to send/receive messages from the IMS infrastructure at the ISC reference points (class IMSISC in Figure 4.4).

- **CNScribeClient** - The *Endpoint* is the only attribute in this class, and it represents the underlying Scribe Client node handle (similar to a mailbox address that is used to send/receive messages in the CN Scribe publish-subscribe infrastructure). This class also implements the methods that use the publish-subscribe infrastructure; for example the *join()* method implements the resource location process via message multicast through the Scribe overlay. The topic subscription process is achieved with the *subscribe()* and *match()* methods, this last is implemented through a callback function (i.e., listener) when a message is published for a topic that the *CNScribeClient* had previously received a subscription.
• CNMsg - This Class represents the CN user data by generalizing the CN metadata messages format (shown as classes msgDIA and msgDID in Figure 4.4). The Topic attribute represents the key used in the resource location process in the publish-subscribe infrastructure. The Presentity and TupleID attributes are used to identify the CN user, where the first has the CN user URI and the second identifies the presence record information.

• PresenceProxy - Responsible for the outbound communication with the users, it generalizes the SIP messages, implemented as PUBLISH and NOTIFY class objects (shown as classes in Figure 4.4) that the CN needs to notify the users. It also implements an UDP client socket, illustrated as the sendMsg() method, that is responsible for sending the messages and handling its responses.

• Workflow - This class implements the service that is responsible for the application workflow in terms of internal messages flow, It is implemented by the method handleEvent(), and error status reporting (explained with detail in Section 4.4.1). That is, the Workflow service was implemented to generalize the concept of the CN process and to ease future extensions (e.g., implementing security mechanisms inside the CN).

4.3.2 CNAS Data Model

The main classes identified for the implementation of the CNAS Data Model component are:

• CNDdata - This class is an aggregation class that contains the information system used by the CN. Its attributes: MediaProfile, TerminalProfile and UserPreferences. Each one represents also a structured information system that can be mapped to MPEG-7 MDS data instance (e.g., a description), this allows a huge flexibility and a powerful information system domain.

• MetadataParser - This class is implemented by a XML parser, given that all messages, internal and external, in the CN are in XML format. The Metadata attribute is a string representation of the XML message and the validate() method is a generic method to parse and validate XML data.

• UMAProfiler - This class is an MPEG-21 Digital Item Adaptation Tool as it adapts the metadata profile for a context based on his class attributes, CNMsg and SubscriberProfile, representing the CN information system (implemented in the adapt() method). This component facilitates the integration of different descriptions of the same resource (e.g., user terminal capability description) by integrating complementary information (e.g., semantic indexing), the result are unique and richer
descriptions matching a specific need or domain (e.g., content related to football events).

- CNOntology - This class is responsible for indexing, validating the context and segmenting the information system present on the CN. This is achieved via the index() method that is, based on the stored ontology (loaded by the SemanticBase class object attribute), process the InstanceMetadata attribute and returns more appropriate values for CN use. These values correspond to the CNScribe topic-keys that build the overlay of topics (groups with similar interests) within the CN P2P infrastructure allowing a more precise resources location process on those topics.

4.4 CNAS services functional characteristics

This subsection describes in detail the main services provided by the CNAS, its organization and functionalities. In particular are described the Workflow, UMA Profiler and Ontology.

4.4.1 Workflow Service

Figure 4.5 shows the workflow operation scenario performed by the workflow class, represented as an UML state diagram. This diagram represents the states that are transversed by the workflow service from receiving a SIP message to inserting a new topic in the database (e.g., metadata joined) and its subscription in the CN.
The workflow operation is responsible for all metadata processing inside the CN, achieved by exchanging objects between the different workflow activities as input or output data. The metadata passes through several "states" that are enumerated as:

- **Initialized** - This indicates that the SIP message that came from the IMS network through the IMS ISC reference point was processed correctly, meaning that the CN is able to process it.

- **Parsed** - This represents the validation step of the presence information contained in the SIP message. If this information is not correct then the metadata is discarded and the originator of the message notified through his Presence service.

- **Extracted** - This represents the searching and segmenting step of the information in order to increase the efficiency of the resource location process.

- **Indexed** - This indicates that the information matched an item in the CN Ontology, this means that there were similar semantic terms for this information in the CN. Moreover, this information will be used by the CN to allow more complex queries about this metadata.

Figure 4.5: CN Workflow Service State Diagram
Joined - This represents the resource location/discovery process in the CN, this is implemented by the CN Scribe overlay through the message multicast facility where the information is inserted.

Subscribed - This indicates that there are CN users that have registered their interest on this metadata, this also means that there are CN users that need to be notified via the Presence Proxy component.

Another operation that is performed by the workflow service is the CN users notification. This happens when a new topic item is inserted in the database (e.g., metadata joined) and there are already CN users with the same subscription. Figure 4.6 shows the notification operation scenario that the CN performs to deliver this notification information to the CN users.

![Figure 4.6: CN Notification Workflow Service](image)

In this process the metadata passes through several "states" that are enumerated as:

- Found - This indicates that a new message (i.e., CN Scribe message) for a topic subscription was inserted in the P2P database.

- Filtered - This represents the validation step of the presence information (e.g., terminal capabilities) contained in the CN Scribe message for the CN users that had a subscription for the arrived topic item. This process is where the metadata is adapted to match the CN Users characteristics (explained in detail in Section 4.4.2).
• Notified - This indicates that the metadata match the interests from CN users. This also means that there are CN users to notify via the Presence Proxy component.

4.4.2 UMA profiler service

The main function of the UMA Profiler Service is to adapt available content and related metadata to the CN users preferences and/or context.

The need for this tool results from the heterogeneity of devices, the number of source coding formats and the consequent complexity of matching content and terminal characteristics and capabilities.

As an example, consider a media broadcast of video with a resolution of 640×480 that is encoded in the AVI format and a user that having a mobile terminal wants to access this video, but is only capable of decoding MPEG video for a display resolution of 176×96. From this example, if no support is provided by the CN it is obvious that the consumption of that content would not be possible. Although if properly designed the CN can provide such type of support either by transcoding content or by finding in the CN if appropriate content is available. In the CN implementation described in this thesis the latter approach is implemented.

The UMA Profiler Service was implemented using the XSLT language [Tid08], that specifies the syntax and semantics of a language allowing the transformation of XML documents into other XML documents providing greater flexibility to configure the parameters used in the metadata adaption. Figure 4.7 shows how this process works.

![Figure 4.7: XSLT Adaption Process](image)

In order to better understand how this process works, Figure 4.8 represents an example of an user terminal capabilities and a stylesheet file (cn_terminal_profile.xsd), used for its transformation. XSLT allows to create templates, these matches on the type of a node enables to treat elements and attributes that have the same kind of content in the same way; templates that match on a substitution group enable to treat elements that appear or not in the same place in the same way.
Figure 4.8: CN UMA Profiler

The use of XSLT enables the dynamic configuration of the items that are used in computation of the terminal profile matching criteria. For example in Figure 4.8 the variables in question are: Resolution Height and Width. The template used to get the values compares them with the media profile only take in account the two correspondent variables Frame Height and Width. If a third variable (e.g, Frame Rate) is also relevant, there is no problem as XSLT templates can use a dynamic process to perform the transformation and display results.

4.4.3 CN Ontology Service

The main purpose of the CN ontology is to guide the definition of the entity instances corresponding to both the Application Specific Metadata and the Domain Specific Metadata. These entity instances correspond to the Scribe topic-keys and allow a more precise resource location process.

The CNOntology is implemented using the Resource Description Framework (RDF) which is a description language that addresses many of the problems found in metadata presentation, RDF has the following characteristics as identified in [DHB+00]:

- Based on simple principles;
- Flexible;
- Extensible without breaking backward compatibility;
- Expressed in well-known formats such as XML;

In the CN implementation described in this thesis extensibility of RDF is linked to another feature, classes. Each resource in RDF can belong to one or more classes, this is achieved
by the Resource Description Framework Schema (RDFS), an extension to RDF that describes how to define RDF vocabularies using RDF itself [BG00].

An RDF document is built up by triples, that can be viewed as a graph where each triple is represented by an arrow from one node to another, the arrows representing the semantics of the property between the nodes. In Figure 4.9 are represented (an example of using) of these triples and its semantics.

![Figure 4.9: CN Ontology Implementation](image)

The powerful search capabilities associated with RDF-based metadata means that it’s possible to state potentially very complex queries. A very important part of the overall usefulness of CNOntology is the ability to provide some simplifying mechanism for complex queries. In the design of the CN Ontology only a minimum set of assumptions were adopted in order to have a very flexible and expandable functionality.

In the CN queries are needed for other tasks than pure searching, notably for segmenting. The CNOntology used to build this query management system will be extended to include editing at some point, as part of future work. Knowing this, it is desirable to make this component extensible to easily add new features.

Figure 4.10 illustrates the query workflow implemented by the CNOntology service.
This iterative process can be described by the following activities:

- **Search** - This indicates that exists a term that will be searched.

- **Substitution** - This represents the process of transforming the term into RDF valid syntax.

- **Query** - This represents the RDF query itself.

- **Mapping** - This represents the crawling through the graph.

### 4.5 Use Case Scenario

This section describes a use case that illustrates how the proposed architecture can support services in a Content Network infrastructure. Figures in this section represent the network elements and messages that they exchange, in the two infrastructures already described in this chapter: IMS and CN middleware.

Content network elements are represented as IMS components (e.g., CSCF and AS), terminals are represented as users or content servers. All the interactions between the content network elements are implemented by IMS control messages. It is also considered that all users and content servers have already registered in the system and therefore:
• Their profile is stored in the associated HSS (e.g., email address, communication preferences, status, etc);

• A consequence of is associated user interest, and content description topics are created in the SCRIBE overlay;

• The appropriate filter criteria have been uploaded to the CSCF (e.g., SIP Header - Event: presence.cninfo);

In the following example is also considered that the CN middleware overlay is composed by three nodes (CNx, CNy and CNz).

### 4.5.1 Register Interests

Let’s consider a user, Rita, had registered her interests in the CN using her presence information. The messages workflow that allow this feature are shown in Figure 4.11:

![Figure 4.11: Use Case - Step 1 (Register Interests)](image)

The first message, is a SIP PUBLISH, with the CN SIP header Event properly filled (shown in Figure 4.12). Due to the previous provision of the appropriate filter criteria in the IMS infrastructure this message is sent to the CN AS overlay and processed (step 1 in Figure 4.11) by the CNAS ISC reference Point.
Figure 4.12: CN SIP Message Header

Rita’s audiovisual content interests and context (e.g., Manchester United, media format, etc) are encoded using the RPID and MPEG-21 DIA formats. Figure 4.13 illustrates Rita’s Presence information extension for the CN.

Figure 4.13: CN Presence Information

This CN presence information is identified by the cnext, the namespace extension used. The entity attribute represents the user and status indicates if this presence information is still wanted. In this case the value "open" indicates that user Rita is still interest in receiving notifications, if the user wants to cancel this presence information tuple the value in the status information must be set to "closed".

In order to allow more flexibility and extensibility inside the CN extension Metadata the messages that represents the users interests are coded in DIA format. Figure 4.14 represents excerpt from the DIA message that contains the Terminal Capabilities (in order simplify reading), in terms of display, storage, network, etc.
The information that describes the user interests is shown in Figure 4.15 and has one CN extension in order to represent the semantic information based on MPEG-7 MDS. The adoption of MPEG-7 provides a richer description capability that fosters resource location effectiveness (as already mentioned in Section 4.3)

The implementation of the necessary information system that supports the CN is based on CN Scribe application nodes seeded with the topic corresponding to the metadata present in the users preferences (users interests and terminal capabilities) and content description.

The CN process begins with the MetadataParser Component extracting the metadata from the presence information conveyed by the PUBLISH message (step 2 in Figure 4.11 )

Next the CNOntology segmentation tool for this information, provides ontology-based semantic indexing capabilities (step 3 in Figure 4.11 ) in order to increase the retrieval effectiveness of resources, in this case CNScribe topic-keys (step 4 in Figure 4.11 ).

For example (illustrated in Figure 4.14 ) may be Rita interested in Manchester United goals and wants to view a particular one that was scored by Manchester United player
number 7. Using our stored domain-specific ontology (represented in the XML files snapshot by the Figure 4.16), it can be extrapolate the player related topic and subscribe it, this is possible by using the namespace present in the semantic description of the user interests (e.g., urn:PersonType:Football-Player).

<SemanticBase id="FootBall-Player" xsi:type='PersonType'>
  <Label>
    <Name preferred='true'>Football Player</Name>
    <Name preferred='false'>Soccer Player</Name>
  </Label>
  <Definition>
    <FreeTextAnnotation xml:lang="en">Person that's play professional FootBall</FreeTextAnnotation>
    <KeywordAnnotation xml:lang="en">
      <Keyword>Footballer</Keyword>
    </KeywordAnnotation>
    <Relation type='urn:isExemplifiedBy' target='Cristiano-Ronaldo'/>
    <Relation type='urn:isExemplifiedBy' target='Luis-Figo'/>
    <Relation type='urn:specializationOf' target='FootBall-Team'/>
  </Definition>
</SemanticBase>

<SemanticBase id="Cristiano-Ronaldo" xsi:type='FootBall-Player'>
  <Label>
    <Name preferred='true'>Cristiano Ronaldo</Name>
    <Name preferred='false'>CR</Name>
  </Label>
  <Definition>
    <FreeTextAnnotation xml:lang="en">Forward from Manchester United</FreeTextAnnotation>
    <KeywordAnnotation xml:lang="en">
      <Keyword>Ronaldo</Keyword>
      <Keyword>Cristiano Ronaldo</Keyword>
      <Keyword>CR</Keyword>
      <Keyword>Manchester United Player 7</Keyword>
    </KeywordAnnotation>
    <Relation type='urn:specializationOf' target='Manchester-United-Team'/>
  </Definition>
</SemanticBase>

Figure 4.16: CN Ontology Sample

In the case the topics of interest aren’t already present in the CN overlay then they are created (step 5 in Figure 4.11) and registered with the topic-keys retrieved from our domain specific ontology (represented in the Figure 4.17 in node CNz by a and b). Finally (step 6 in Figure 4.11), the CN updates the presence information for the topic’s subscribers sending SIP PUBLISH/NOTIFY messages to the respective Presence Servers (in this case only Rita’s presence is notified by messages for this topic) through the PresenceProxy Component.

Figure 4.17: CN Overlay

It’s important to note that Presence Servers illustrated in this example are not mandatory, in fact if they don’t exist the CN is able to notify the presentities directly by sending
the respective NOTIFY message, to achieve this the CN only has to configure the PresenceProxy to do so.

### 4.5.2 Publishing Content

In the second step of the running example the content provider, SoccerTV, starts broadcasting a Manchester United match. This event is announced to all the users in the CN that have an interest in this type of event (soccer) by matching the users interests and content descriptions. The associated message workflow is shown in Figure 4.18.

![Figure 4.18: Use Case - Step 2 (Publishing Content)](image)

The first message PUBLISH in the Figure 4.18, the content provider SoccerTV announces is appropriately a new content. As it happened in the previous step the CN SIP header Event filled and due to the previous provision of the appropriate filter criteria in the IMS infrastructure the PUBLISH message is sent to the CN AS overlay. The new content described in PUBLISH message body (or Digital Item in MPEG-21 terminology) has two resources; High Resolution shown in Figure 4.19 and Low Resolution shown in Figure 4.21.
This message conveys a Manchester United match audiovisual content descriptions using the RPID and MPEG-21 DID formats. Figure 4.20 illustrates content provider SocceerTV Presence information extension for the CN.

The entity attribute represents the user (in this case the broadcaster) and status indicates if this presence information is still active, in this case if the content provider wants to stop the event broadcasting the value in the status information must be set to "closed".

It is important to notice that there are no different behaviors, in the CN, (consumer/producer) that is all users can potentially be producers and/or consumers. For example content provider soccerTV could "publish" its interests about users in the CN that are streaming media from the same event and then use this knowledge to provide smart advertising. Similarly Rita could also announce several media profiles in the same DID message by using different descriptions for the media Figure 4.21.
Finally the semantic description of the media can also be present in the DID message as well as it is in the DIA message. This descriptions represent semantic information based on MPEG-7 MDS, therefore providing a rich description capability that may enable a more effective resource location (as already mentioned in Section 4.3).

...<Video>
...<Mpeg7>
...<Item>
...<DIDL>
...<cnext>

Figure 4.21: CN DID Message for Low Resolution

Figure 4.22: CN DID Message Semantic Description
4.5.3 Receive Notifications

It is also important to notice that the process for joining the CN is the same for users and content providers. Similarly that in 4.5.1 (Rita’s register preferences), the CN handles the metadata present in content presence information in order to organize and use the CN infrastructure (as already mentioned in Section 4.3). However in the resources location process (step 7 in Figure 4.18) it is found that the soccer topic (with topic-keyc “a” as shown in Figure 4.17) is already present in the node CNz. In this case instead of inserting this topic in the CN CNx joins the multicast overlay on topic a (shown in detail in Figure 4.23).

![Figure 4.23: CN Overlay](image)

In the final interaction, the CN updates, using a PUBLISH message, the presence information to the topic’s subscribers (as is the case for Rita and SoccerTV), announcing by this way the changes in the CN. However before this notifications the CN “filter” (step 8 from Figure 4.18) the information that is sent in this messages, in order to respond to CN users specific needs. The process was implemented taking in to account the MPEG-21 Digital Item Adaptation Tools [ISBK06] concepts. An important feature of these updates for content providers is that they can not only announce their content to consumers (e.g., Rita), but also by receiving presence information updates they can also verify the end-users interest on different types of content. Content providers can also use this information for content adaptation or smart advertising.
Chapter 5

Tests and Results

This chapter presents the functional and non-functional tests that were performed in order to assess the implemented CN platform (showed in Chapter 4). The first section describes the usage case scenario (showed in Chapter 4) tested in a demo application build using open-source software. The second section describes the results obtained by deployment of tools for performance testing, namely by assessing objective quality of service parameters.

5.1 Functional tests and demo

5.1.1 Objectives and architecture

The main goal of the functional tests that were performed was to assess if the proposed platform and its implementation could meet the requirements identified in Chapter 2.

These functional tests were conducted using the architecture illustrated in Figure 5.1.

Figure 5.1: CN Demo Architecture
5.1.2 Components and configuration

The IMS test components were deployed using FOKUS Open IMS Playground Software [MW05]. This is an open source technology that deploys a test platform to validate existing and emerging IMS standards and to extend the IMS functionality by enabling new types of multimedia applications on top of different access networks as well as a service creation toolkit.

In the CN Demo the Application Server (to be precise an P2P overlay network), in this case our CN Middleware (see Chapter 4 for details) was deployed within the IMS test bed and using the Scribe P2P infrastructure. For terminal emulation and streaming server it was used a “customized” version of UCT IMS Client and UCT IPtv Streaming Server [WGSV08] respectively.

In order to use the FOKUS Open IMS Playground Software it is necessary to configure the FHoSS component (Fokus implementation of the HSS). This is the master database of IMS infrastructure storing IMS user profiles including individual filtering information, user status information and application server profiles.

The first step is to configure a new Application Server, in this case the CN Middleware, in four basic steps: the result of this process is shown in Figure 5.2

1. Add an application server (e.g, the server runs on port 9090);

2. Add a trigger point (e.g, SIP Header Event : presence.cninfo);

3. Link the application server and trigger point with the initial filter criteria;

4. Add the IFC to the default service profile;
The second IMS configuration required is to configure another Application Server, to emulate the soccerTV provider in order to allow users to connect to the media that will be announced in the CN. The configuration process is similar to the CN Middleware only with different variables values as shown in the Figure 5.3.

For deploying the media server the software used was a “customized” version of the UCT IPTv Streaming Server. The alterations made to this software consisted of adding the capacity to publish presence information based on MPEG-21 DID for the content
that it made available. Figure 5.4 shows the activity diagram that reflects in detail the changes made in order to use this software in the CN demo.

After validating the content related parameters the \textit{CNBuildMetadata} component uses information from the audiovisual material to create the metadata associated to it. This is based on media characteristics found in the material (e.g., video resolution) plus the semantic description (e.g., who, what, when descriptors) that could be present in the content file or in another source (e.g., a Multimedia Database). The objective is to create a description based on the MPEG-21 DID standard as illustrated in Figure 5.5.
The CNPublishPresence component is responsible for the creation of a SIP PUBLISH message that conveys the presence information referring to the content available in the Streaming Server to the CN.

For the emulation of users terminals it was used a “customized” version of UCT IMS Client. This version enables the encoding of audiovisual content interests (e.g., Manchester United, preferred media format, etc) using the RPID and MPEG-21 DIA formats as illustrated in Figure 5.6.

This user terminal emulator provides the media access functionality and allows viewing/canceling of CN subscriptions. Figure 5.7 shows a screen of the terminal emulator.
The CN main functionalities implemented on the IMS Client were:

- Upload of XML encoded file in the RPID and MPEG-21 DIA formats, and conveyed using a SIP PUBLISH message;

- Enable the media access triggered by a subscription notification;

- List all active interest subscriptions in the CN;

- Cancel a subscription in the CN;

5.1.3 Functional test results

Figure 5.8 shows the CN demo client terminal where the set of exchanged messages are represented as well as the response to a particular query.
The results for the demo were very good given that all functional requirements identified as use case in Chapter 2 were met and therefore it was possible to implement the scenario presented in Chapter 4. This means that this demo served as a proof of concept for CN platform which Conceptual Framework and Architecture have been presented in this thesis.

5.2 Non-functional tests and results

5.2.1 Objectives and architecture

This section presents the results obtained by deployment of tools for performance testing, with an aim of testing relevant objective quality of service parameters for the CN Middleware solution. These tests allowed also a more precise understanding of the impact of using ontologies on the content indexing process and its response capability for CN Middleware deployment. Four different tests were performed: the first test measured the hit rate; the second served to measure the database growth size and the third and fourth tests measured the solution scalability in terms of its response time. Figure 5.9 shows the architecture deployed for this tests.
5.2.2 Components and configuration

These tests were implemented using the SIPp testing tool [GJ08]; a SIP workload generator (another freely available open-source tool). SIPp allows a wide range of SIP scenarios to be tested, such as user-agent clients (UAC) and user-agent servers (UAS). SIPp is also extensible by writing third-party XML scripts that define new call flows.

For the tests performed it was only used the user-agent clients (UAC) in order to simulate the clients requests to the CN. The different types of non-functional tests performed were implemented by writing the appropriate SIPp XML scripts. The concepts explored in this thesis were present in the new flows in order to include the information (namely MPEG-21 DID and DIA messages) needed for the CN Middleware software operation.

The experimental setup was composed by the following components:

- **Hardware** - It had two components: the server that supported the CN Middleware was a Intel(R) Core(TM)2 Duo CPU T9300 @ 2.50 GHz running Ubuntu Server Linux with a 2.6.24-19 kernel, with 3GB memory. The PC hosting the clients to generate load was a Intel(R) Pentium(R) 4 CPU 3.4GHz processor and 2GB memory. The network connection was composed of a cross cable between the two processors network cards (100 MB Ethernet).

- **Configurations** - The CN database was populated with a set of registries that corresponded to the topics (i.e., keywords) that it could provide. This was generated with random data using a power law distribution. The estimated database teoric limit follows the $m^n.(2^n - 1)$ function. This correspond to the Power Set of the number,
n, of variables used in the query made (it was not considered the empty set). For
the all experiences the sets of registries considered that $m = 10$ that correspond to
different keywords and $n = 3$ witch represents the number of variables used by the
different keywords.

- Scenarios - The first test scenario consisted in searching, and 1000 queries were
performed in the CN database when using the semantic indexing based on a ontology
and without using semantic indexing. The second test consisted on the creation of
different topics in the CN database, with each set of registries (using a different
number of keywords). The third and fourth test consisted in executing 1 query and
wait for the first and last responses using 1, 10, and 50 CN nodes. In all results
presented the error bars are defined for a 95% confidence interval.

5.2.3 Results

Query hit rate

The first test made was intended to survey the benefits of using a ontology to semantic
index and filter during the resource location process in the CN, Figure 5.10 shows the
probability density function (PDF) of having at least one response to an query against
the number of registries in the CN database. The results clearly demonstrate the quality
improvement in the querying hit rate when semantic indexing is used on the CN by using
an ontology.

Another important conclusion is that when there are only a few registries in the
database the query with semantic base indexing was much more efficient. This can be
very useful when dealing with the long tail phenomena [CKR+07] that is present in the
set current and popular of content in the Internet (e.g., youtube, flickr).
Figure 5.10: CN Ontology Quality Test

This test measured the evolution of the database size with the number of registries and surveyed its scalability. This test assesses the number of topics created in the database when using or not an ontology for indexing the terms. With no ontology the number of topics in the database grows in a sub-linear form. Figure 5.11 also shows that when the ontology is used for indexing purposes the database size is not only an order of magnitude smaller but also that it increases in a more controlled way, that is it should reach its theoretical limit later.
Query first response time

This test measured the time for obtaining a first response to a query. This test assesses the scalability and efficiency of the CN Middleware software and allows to understand how the CN behaves under different configurations (e.g., number of nodes, database size). Figure 5.12 shows that while the database doesn’t have a significant size the best performance is achieved by using just one CN node. When the database size increased significantly the best configuration was found with ten CN nodes. The fact that this was not achieved when the number of nodes was the largest (50) may indicate that the time spent by CN nodes in the P2P message flow may in certain conditions (notably small database size) impair the CN performance.
In absolute terms it can also be concluded that for reasonable database sizes (<100,000 entries) the delay introduced by the CN Middleware is very small (<100 ms) and therefore adequate for practice purposes.

**Query last response time**

This test measured the time required to obtain all the responses to a query. The main difference from the previous test is that the time is measured from the moment that the query is made until the last response is received.

This test is relevant for example for content providers that may want to know the identity of all the users with a particular interest. Figure 5.13 shows that the CN with ten nodes was the best configuration, this could indicate that the time spent by CN nodes in the P2P message flow may impair the CN performance when a greater number of nodes is involved.

The poor response times obtained with just one node and a large database size may be justified by the fact that in this case there is no distribution of the metadata database, and therefore no benefits of a distributed CN architecture is exploited.
In absolute terms it is quite important to note that while the results are perfectly acceptable (<1000 ms) for small database sizes that is not the case for larger database sizes. This could be due to the fact that the load distribution property of the P2P infrastructure is not used as there is only one physical node (with multiple logical nodes) in the CN middleware. If this problem can be mitigated by being several physical P2P nodes is an issue open for further study.
Chapter 6

Conclusions and Future Work

6.1 Conclusions

The chief problem that is tackled in this thesis is the content resource location/consuming, where this context is highly dynamic/dispersed (e.g., inter-personal communications, Web 2.0 powered web sites) and at the same time take to into account terminal and network heterogeneity and users’ context and preferences.

The proposal described in this thesis is a platform for the deployment of Content Networks based on a Conceptual Framework and Architecture that are also described within this thesis.

Presence and content descriptions based services are considered central concepts/tools within this proposal.

The proposed Conceptual Framework is based on the identification of two central concepts for these services (presence and audiovisual multimedia descriptions), and explores their combined usage. Another important contribution is found in the fact that existing standards for presence (PIDF, RPID) and audiovisual metadata (MPEG-7, -21) already have in place the necessary tools for this elementary functionalities and for their mutual integration.

One relevant challenge in the provision of Content Network services that is tackled by the proposed architecture is the heterogeneity that can be found at the Transport and Service layers. The solution proposed for this problem is the usage of IMS and a CN middleware based on P2P technologies.

Another challenge that is considered in this thesis is resource location and structuring within the Content Network. For this problem the solution proposed is to use the semantic interoperation achieved through domain knowledge that supports semantic retrieval and filtering, which was expressed by an ontology.

In order to access the desired functionalities of the CN some use case scenarios were identified, these usage scenarios illustrate the behavior of the CN components and in
particular, the message flows in IMS and CN Middleware. These usage case scenarios were tested in a demo application build using open-source software. This demo was used as a proof of concept for the Conceptual Framework and Architecture proposed and for functional requirements assessment.

The tests that were carried for measuring objective quality of service, these parameters included hit rate and query response delay and were measured under different conditions and settings (e.g., using or not an ontology). For the services provided in the Content Network demo, the results showed that the solution could meet the set of functional requirements identified for these services and also presented good scalability and efficiency properties in its non-functional aspects.

Finally, the work on this thesis also contributed to the open-source community by identifying and commenting on bugs found on the different used tools and to the academic community by presenting a paper [RL07] at Middleware 2007 Conference on Workshop on Middleware for next-generation converged networks and applications.

6.2 Future Work

Although the goal of this thesis has been met, there are still several aspects that are worthy of consideration in future research. Therefore, to learn more about the Content Network platform presented and its behavior in various real network conditions, a set of experiments on the Internet is necessary. The plan is to improve the prototype and deploy it on PlanetLab [Pla08] evaluating its performance in a real scenario testbed, this deployment can broaden the scope of tests in terms that allow the evaluation of objective and perceived service quality for different parameters (e.g., matching relevance, usability, etc).

The resource matching issue is where the CN may need improvement in order to support more complex queries.

An important research area that should also be considered is to investigate how the proposed CN middleware infrastructure can be extended beyond audiovisual content metadata. One of the extensions to be explored could be dynamic service creation, deployment and execution depending on context.
Bibliography


[CKR’07] Meeyoung Cha, Haewoon Kwak, Pablo Rodriguez, Yong-Yeol Ahn, and Sue Moon. I tube, you tube, everybody tubes: analyzing the
world’s largest user generated content video system. In IMC ’07: Pro-
cedings of the 7th ACM SIGCOMM conference on Internet measure-
ment, 2007.

[CRS00] A. Rubens C. Rigney, S. Willens and W. Simpson. Remote authenti-

[CTC05] Fotis Kazasis Chrisa Tsinaraki, Panagiotis Polydoros and Stavros
Christodoulakis. Ontology-based semantic indexing for mpeg-7 and
tv-anytime audiovisual content. Multimedia Tools Appl., 26:299–325,
2005.

[CTC07] Panagiotis Polydoros Chrisa Tsinaraki and Stavros Christodoulakis.
Interoperability support between mpeg-7/21 and owl in ds-mirf. IEEE

[DHB\textsuperscript{+}00] Stefan Decker, Frank Van Harmelen, Jeen Broekstra, Michael Erd-
mann, Dieter Fensel, Ian Horrocks, Michel Klein, and Sergey Melnik.
The semantic web - on the respective roles of xml and rdf. IEEE

[DM03] Rajan Lukose Kiran Nagaraja Jim Pruyne Bruno Richard Sami Rollins
Zhichen Xu Dejan Milojicic, Vana Kalogeraki. Peer-to-peer comput-

[FCNP02] Touradj Ebrahimi Fernando C. N. Pereira. The Mpeg-4 Book. Prentice
Hall PTR, 2002.

[FDS03] P. Druschel J. Kubiatowicz F. Dabek, B. Zhao and I. Stoica. Towards a
common api for structured peer-to-peer overlays. Peer-to-Peer Systems


[Has98] Atul; Netravali Arun N.; Langdon Glen G. Jr. Haskell, Barry G.; Puri.
Digital video: An introduction to mpeg-2. Journal of Electronic Imag-

[HS06] Alan B. Johnston Henry Sinnreich. Internet Communications Using
SIP Delivering VoIP and Multimedia Services with Session Initiation


K. Knuettel Magedanz, D. Witaszek and P. Weik. The ims playground @ fokus an open testbed for next generation network multimedia services. In *TRIDENTCOM ’05: Proceedings of the First International Conference on Testbeds and Research Infrastructures for the DEvelopment of Networks and COMmunities*, 2005.

N.Freed and N. Boreinstein. Multipurpose internet mail extensions (mime) part 1 format of internet message bodies. Rfc2045, IETF, 1996.


Appendix A

Curriculum Vitae

**RIBEIRO, EDUARDO FILIPE FREIRE**
eduardo.ribeiro@dualsecurity.com

**Nationality**
Portuguese

**Date of birth**
28/08/1977

**Work Experience**

- **Dates**: September 2002 onwards
  - **Name and address of employer**: Caixa Geral Depósitos, 63, Av João XXI, 1000-300, Lisbon, Portugal
  - **Type of business or sector**: State financial institution
  - **Occupation or position held**: Analyst Programmer
    - Functional and technical analyst for the Internet banking, responsible for design and integration of new processes into the existing Java2 environment.
    - Team leader and designated architecture officer, responsible for the auditing, improving and resource planning in the Internet banking area.

- **Dates**: September 2000 - August 2002
  - **Name and address of employer**: Pararede, 12-3º, Rua Laura Alves, 1050-138, Lisbon, Portugal
  - **Type of business or sector**: Information technology and systems
  - **Occupation or position held**: Consultant
    - Developer in projects for the financial and retail areas.
    - System analyst in the business integration unit, working with messaging and communications systems.

- **Dates**: July 1997 - August 2000
  - **Name and address of employer**: S.D.F Portugal, EN.10, Entreposto Frigorífico, 2615-179, Alverca, Portugal
  - **Type of business or sector**: Logistics
  - **Occupation or position held**: Customer Manager
### Main activities and responsibilities
- Responsible for the interface between the logistic platform and the customer, managing the stock, the provision and all the inherent operation process.
- Work in integration projects, mainly business processes and Electronic Integration (EDI).

### Education and Training

<table>
<thead>
<tr>
<th>Dates</th>
<th>Name and type of organization providing education and training</th>
<th>Principal subjects/occupational skills covered</th>
</tr>
</thead>
</table>
| 2000        | Rumos, 56, Campo Grande, 1700-093, Lisboa, Portugal          | - Object Oriented Programming  
- Java Programming  
- Advanced C Programming  
- Unix Administration  
- Networking Technologies  
- Microsoft "Networking Essentials"  
- Microsoft "System Administration for Microsoft SQL Server 7.0"  
- Microsoft "Mastering COM Development Using Ms Visual C++ 6" |
PERSONAL SKILLS
AND COMPETENCES

MOTHER TONGUE
Portuguese

OTHER LANGUAGES
English                        French
• Reading skills              Good                        Good
• Writing skills              Good                        Basic
• Verbal skills               Good                        Basic

ORGANIZATIONAL SKILLS
AND COMPETENCES
- Member of Openoffice.org portuguese group, participation in portuguese native language build and locale for version 1.1.

TECHNICAL SKILLS
AND COMPETENCES
- OO Design and Analysis: UML.
- Programming Languages: Java, C, PHP, C++, Perl, Ruby, Shell Scripting, XML and .NET(C#).
- Operating Systems: Linux, AIX, Solaris, Windows and Cisco IOS.
- Databases: Mysql, Informix, Oracle and Microsoft SQL Server.
- Networking: TCP/IP (HTTP, SIP, SMTP, POP3, IMAP, DNS, FTP, TCP, UDP, IP) and SNA (LU6.2).
- Office Tools: MS Office, Openoffice.org and MS Project.

ADDITIONAL INFORMATION

PUBLICATIONS