Abstract

This paper introduces a suitable way for indexing multimedia metadata on a structured Peer-to-Peer overlay network, with special care to the management of rights metadata expressed by MPEG-21. We have selected a suitable subset of MPEG-21 Rights Expression Language elements to be indexed, in order to map governed contents into a flat space and allow insertion and retrieval of digital contents. Furthermore, we present a distributed application built on a structured overlay network enabling the search of multimedia items using rights related information. Our solution is completely decentralized and can be exploited in any MPEG-21 compliant metadata representation.

1. Introduction

When the WWW was born, in the early 90’s, it was mainly designed to exchange scientific results based on text. The protocol enabling what we know as Internet is actually based on text. Using metadata (i.e. description of the data) it is possible to enhance and enrich the structured information related to a content and to search and retrieve digital items. Detailed metadata require a complex structure to be inserted on and a common understanding of metadata can be guaranteed only by the adoption of standards. In this paper we propose the adoption of standards used by a fast growing number of scientific communities: MPEG-7 [2] to describe metadata related to the digital items and MPEG-21 Rights Expression Language (REL) [1] to describe metadata related to the associated license. With the use of metadata we can cover the lack of structured information but we have to design a suitable way for storing and searching them. Metadata are usually stored in relational (RDB) or object oriented (OODB) databases, mapped to related tables as well as objects. Since the beginning of year 2000, XML was introduced for structuring data and metadata. The database approach (R/OODB or XML like) forces a central architecture: the central component (i.e., the database, even if mirrored or replicated on some topology) can become the bottleneck of the communication process during the storing and retrieving phases. The introduction of Peer-to-Peer (P2P) systems allows the distribution of metadata in an efficient way, avoiding single-point-of-failure and, in case of structured P2P systems, guaranteeing high scalability. The price to be payed is the limited functionalities concerning the metadata structure to be indexed. Structured P2P systems present a flat space of indexes (an exception is represented by CAN [9], that is d-dimensional), therefore each resource and each node is indexed with a key computed in some way from the same space. This paper introduces a suitable way for indexing structured metadata on a Distributed Hash Table (DHT), with special attention to the metadata representing rights based on MPEG-21 REL. We present a distributed application built on a structured overlay network, tailored to insert structured information on a flat space, enabling a hierarchical indexing scheme like the one described in [7]. To the best of our knowledge, this is the first attempt to index rights metadata in a structured P2P network, where media contents can be exchanged and shared according to the expressed grants.

2. Related Works

The proposed framework makes use of MPEG-7 and MPEG-21 standards for metadata representation and DHTs for network topology. MPEG-7 [2], formally named Multimedia Content Description Interface, provides a rich set of standardized tools to describe multimedia contents. It mainly focuses on description of the digital items, without considering how and where this information is used. MPEG-7 standard has been included in several metadata language, such as ODRL (from W3C) and has been cou-
pled with other important TV ontologies (e.g., TVAnytime [6]). Concerning digital rights, MPEG-7 provides a standard XML schema and the metadata to define conditions for accessing the content (including links to a registry with intellectual property rights data and price) and additional information about the content (copyright pointers, usage history, broadcast schedule). An MPEG-7 Query Format reached the Final Committee Draft, during last MPEG meeting in October 2007. Moreover several query frameworks based on MPEG-7 are still under investigation [10].

MPEG-21 [1] differs from MPEG-7 because its aim is the definition of a normative open framework to be used by all the players in the delivery and consumption chain. This open framework will provide content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market. The goal of MPEG-21 is the definition of a standard technology needed to support users to exchange, access, consume, trade and otherwise manipulate digital items in an efficient, transparent and interoperable way. In particular part 5 of MPEG-21 defines a Rights Expression Language (REL) to be used in the description of customized rights applied to any digital item, since it is seen as a machine-readable language that can declare rights and conditions defined in the Rights Data Dictionary (also standardized by MPEG-21). Rights metadata are expressed by means of MPEG-21 REL, which describes the license associated to a specific resource, along with several available rights (play, copy, modify, print, etc.).

According to the schema shown in Figure 1 (taken from [3]) we can imagine the license as made up of an issuer (with multiplicity 0 or 1), an undefined number of grants (multiplicity 0 or more), and a principal (multiplicity 0 or 1). The issuer is the owner of the rights associated to a given content (eventually coincident with the creator or distributor of the resource) and can assign a given right (e.g., the authorization to copy or modify the content) to the principal. For example, in a CreativeCommons license the principal is missing because it is a license intended for everyone.

![Figure 1. Simplified diagram of a REL license.](image)

Distributed Hash Tables (DHTs) [11] are decentralized systems that partition the ownership of a set of keys among participating nodes. The core function of a DHT is the lookup(key) function that returns the node responsible for that key. Given a message and a key, the DHT routes the message to the node whose identifier is closest by some metrics to the key, in less than \( \log_2 N \) hops, where \( N \) is the number of nodes. Lately, structured P2P systems gained much interest because of their scalability, robustness and efficiency. These properties allow them to be the base layer of many distributed applications for different domains (file-sharing, distributed storage, streaming). DHTs present anyway the following problems: (a) bootstrapping: a user must know a node already in the network in order to join the system; (b) key based routing: as nodes and resources are indexed with unique identifiers (e.g., 160 bit), computed through a hash function (e.g., SHA-1), at the application level knowing the exact identifier a resource is indexed with in order to retrieve it is often an issue; (c) consistency: it takes time to update routing information and references to previously inserted resource.

Focusing on the retrieval of resources, the impoverished query language due to the key based routing (i.e., no support for complex queries) is focused in [5], where authors give an entity-relational view to the P2P search mechanism. An index based query mechanism is presented in [4]: given a broad query, a user can obtain additional information about the data items that match the original query, recursively querying the DHT layer.

3. Indexing and Retrieving Rights Metadata

In the proposed scenario, we suppose that a digital resource is associated to a wide range of metadata, spanning from MPEG-7 multimedia content descriptions to MPEG-21 rights management. Given a resource \( R \) and a set of metadata \( M_R = \{m_0, m_1, ..., m_i\} \), we compute the identifier \( id_R \) and the set of identifiers \( I_{M_R} = \{id_{m_0}, id_{m_1}, ..., id_{m_i}\} \). Each identifier must reference \( id_R \), in order to allow metadata based queries. In other words, we insert on the DHT a set of \( <key, value> \) pairs in the form \( <id_{m_i}, id_R> \), \( \forall id_{m_i} \in I_{M_R} \) and the relation \( <id_R, R> \). This basic scheme allows a user to retrieve the resource associated to a metadata \( m_i \). The system calculates the identifier \( id_{m_i} \) and, by means of a lookup(id_{m_i}), the related resource identifier \( id_R \) and, then, \( R \) itself. To lighten the load of each node, we do not index all the metadata: we chose a subset of the overall tags, used for a first step of the query process. To refine the result set it is possible to query locally the retrieved resources against the complete schemas through well-established approaches. This hybrid strategy can lead to a good trade-off between efficiency, scalability and query expressiveness.

The problem we are facing here comes from the flat identifier space of most of DHTs: the structured nature of metadata (e.g., a XML-based representation) must be mapped in
a flat set of \(<\text{key}, \text{value}\)> pairs. To solve this problem, we propose a hierarchical indexing scheme. The first operation is to gather the keywords for the content to be indexed. We can divide contents between governed and non-governed. Ungoverned items do not have licenses associated and the keywords to be indexed are just the (MPEG-7 elements) name, author and resource description (e.g., size, creation date, and so on). Governed items have a license and we have defined the following structure to be indexed: for each right described in the license we index three MPEG-21 REL elements: issuer, right, principal (see Section 2). Although typical licenses contain one or more grants, we assume in the following a single issuer and a single principal for each right and for every grant expressed in the license we index the bundle of issuer, right and principal linking the associated content. Hence the DHT contains the indexes of the general purpose metadata and in addition, for governed resources, the bundle of grants linking the digital item.

After building the resource \(R\) and calculating its identifier \(id_R\), a key is calculated for the issuer, right and principal metadata \((id_i, id_r, \text{and} id_p, \text{respectively})\). In order to allow more complex queries, we insert on the DHT several mappings for each resource. We first insert the issuer, the right and the principal (as well as typical MPEG-7 tags, such as title and author):

\[
< id_i, id_R > ; < id_r, id_R > ; < id_p, id_R >
\]

Furthermore, we insert all possible combinations of those three metadata by combining the identifiers in order to achieve the following mappings:

\[
< (id_i, id_r), id_R > ;< (id_r, id_p), id_R > ;< (id_i, id_r, id_p), id_R >
\]

Since several identifiers point to the same resource, for example a user could search for “all the digital items issued by someone”, or could submit composite queries like “all the contents with a grant of copy issued by someone”, beyond looking for titles and authors. Since the identifiers in \(I_{M_P}\) are built using MPEG-21 REL tags, it is easy to combine them in order to build those complex identifiers. In our opinion the issuer, right and principal metadata (combined together and with other MPEG-7 tags) are able to provide a good balance of expressiveness to the query mechanism.

In summary we are indexing rights metadata on a structured overlay network, allowing users to search governed resources looking for specific issuers, grants or principals. A user querying the DHT for a resource can start looking for a specific issuer: the returned result set will be the set of all the resources inserted by this issuer (if any). Our scheme allows more specific queries, simply combining previous identifiers and computing the new complex ones.

4. Prototype

In order to implement the indexing scheme described in the previous section, we need a platform enabling the creation and consumption of governed and protected contents. Accordingly, we adopted Chillout\(^1\) that is the reference software implementation of the Digital Media Project (DMP\(^2\)), a non profit organization that has recently approved version 3.0 of its specification, called Interoperable DRM Platform (IDP-3.0). Chillout is also the reference implementation of ISO/IEC 23000-5 Media Streaming Application Format, targeting the distribution of governed content over streaming channels. Chillout is released as Open Source Software (OSS) under the Mozilla Public License v.1.1, it can virtually handle any type of audio-visual resource and allows to create content with in line or referenced resources and metadata describing them. Chillout can handle both contents governed by a license only (a CreativeCommons-like approach) and at the same time contents governed by a license and also protected by encryption techniques, thus enabling a broad variety of application scenarios and business models. Anyway, it is worth noticing that our proposal is completely unbound from a specific reference implementation and it can be implemented in any MPEG-7 and MPEG-21 REL compliant solution.

According to Chillout reference implementation, two file formats for managing digital contents are used: DCI (DMP Content Information) and DCF (the DMP Content File). DCI format is used to specify the metadata for content description and the rights and eventually the protection information for the resource. The DCF is the wrapper of the DCI and of the resources described by the DCI. The resources can be stored within the DCF file or can be referred to by means of pointers. All the metadata are kept inside the DCFS and appropriate parsers and writers for reading and storing metadata by DCF have been implemented.

The proposed implementation is made up of three main modules, as shown in Figure 2. We used FreePastry\(^3\), an open source implementation of the Pastry DHT [8] for our base layer, responsible for the routing infrastructure. However, we built our system exploiting the separation level between the FreePastry implementation and the applications, for having the possibility of using other DHTs. The \(DHT\) module exports to upper modules the insertion of new mappings and the retrieval of the key’s root functionalities. The \(Transport\) module is not put directly on top of the DHT, but communicates with it in order to get the information about the two (or more, e.g., for multisource download) endpoints of the direct connection established for downloading the DCF. This module is composed by two components: one is

\(^{1}\)http://chillout.dmpf.org, Last visited: 15 Feb 2008


\(^{3}\)http://freepastry.rice.edu, Last visited: 15 Feb 2008
responsible for transferring the resources (multimedia files) and the other is responsible for transferring the related metadata, actually a java object which wraps the DCF file. Over the two previous components, the Application module provides the basic functionalities to index, search and exchange resources in a distributed way.

Figure 2. System overview

In order to underline the overall functionality of the proposed system, we describe an example of usage applied to typical use cases. Suppose a musician wants to promote his compilation and decides to distribute her new songs using a P2P network. For promotional purposes the songs are published using a CreativeCommons license, so that the intellectual property of her songs can be acknowledged, although the songs are made freely available for everyone. Accordingly, each song in the compilation is associated to a single resource (e.g. an mp3 file) and packaged in a DCF file. The musician can choose, for example, some restrictions like temporal or geographical limitations. The DFC wrapper contains both MPEG-7 and MPEG-21 information, such as author, date of creation, owner, rights and license for each song. Our solution is able to index the selected metadata, providing to the end user the ability to search and consume the songs accordingly to the license specified by the musician.

5. Conclusions and Future Works

In this paper we presented a suitable approach for indexing and searching structured metadata related to multimedia contents on a DHT. We focused on digital rights information that is expressed according to MPEG-21 REL standard. A scheme for indexing structured information on a flat space is proposed. The creation of a distributed index in a structured overlay networks allows an efficient distribution and retrieval of relevant metadata. Moreover, a prototype based on Chillout reference implementation is given. As a future work, we want to exploit this platform to build an experimental testbed for advanced techniques, such as the similarity search, also for IPR features.

Acknowledgments

This work was partially supported by the SAPIR project, funded by the European Commission under IST FP6 (Contract no. 45128) and by the Ministero Italiano per l’Università e la Ricerca (MIUR) within the framework of the PRIN “PROFILES” project.

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5http://dit.unitn.it/profiles, Last visited: 15 Feb 2008