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Abstract

Within the MPEG-21 Multimedia Framework, Digital Items are introduced as a structured digital representation for multimedia. To facilitate the representation of Digital Items which include secure or controlled content, the authors have implemented an IPMP Digital Item Declaration Language (IPMP DIDL). This provides for a protected representation of Digital Item structure, allowing the use of existing DRM systems and rights expression languages. This paper examines the design and implementation of the IPMP DIDL and its incorporation into MPEG-21 Part 4: IPMP Components.

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A Protected Digital Item Declaration Language for MPEG-21

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Abstract

Within the MPEG-21 Multimedia Framework, Digital Items are introduced as a structured digital representation for multimedia. To facilitate the representation of Digital Items which include secure or controlled content, the authors have implemented an IPMP Digital Item Declaration Language (IPMP DIDL). This provides for a protected representation of Digital Item structure, allowing the use of existing DRM systems and rights expression languages. This paper examines the design and implementation of the IPMP DIDL and its incorporation into MPEG-21 Part 4: IPMP Components.

1. MPEG-21 Multimedia Framework

The MPEG-21 Multimedia Framework has been designed to address the need for interoperable access to content across heterogeneous networks and devices [1]. Digital Items are the currency within the MPEG-21 framework, encapsulating multimedia content and related metadata. The Digital Item Declaration (DID) Model defines a set of entities in Digital Items, and principal examples of these are:

- *Resources* which link to individually identifiable assets, such as audio or video files
- *Components* encapsulating and linking metadata with *Resources*
- *Items* encapsulating *Components* and sub-*Items*
- *Containers* encapsulating a collection of *Items*

The Digital Item Declaration Language (DIDL) provides a Representation of the DID Model, allowing the makeup, structure and organization of a Digital Item to be conveyed in a Digital Item Declaration (DID), which is an XML document. DIDL includes elements corresponding to the entities of the DID Model and defined in the normative XML Schema for DID [2]. Figure 1 shows an example Digital Item, which contains a picture and an associated text descriptor, and its representation in DIDL.

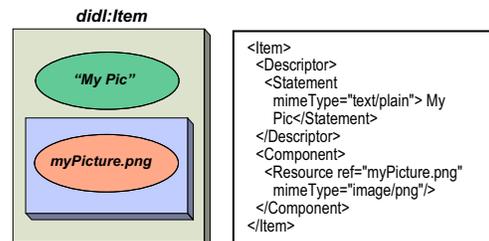


Figure 1: Example Digital Item

Other parts of MPEG-21 include Digital Item Identification (DII), which specifies Identifiers used to identify Digital Items, and parts and collections thereof [3]; the MPEG-21 Rights Expression Language (REL) which expresses the rights, terms and conditions applied to content [4]; and Intellectual Property Management and Protection (IPMP) Components, which provides for the management of rights and intellectual property through the use of protected Digital Items [5].

2. The need for a protected Digital Item Representation

One of the goals of Digital Items is that content subject to copyright, privacy controls, and other forms of intellectual property management can be conveyed alongside metadata describing that management. A key issue, however, is that since DIDL is cleartext XML, the possibly sensitive contents of the Digital Item are exposed to view; this allows unauthorized perusal of rights expressions and keys. In response to the pressing need for an alternative, protected Representation of DID Model structure, the authors designed and implemented the IPMP DIDL detailed in this paper.

3. Design of the MPEG-21 IPMP DIDL

In designing the IPMP DIDL, the authors recognized the importance of maintaining the Digital Item structure defined in the DID Model, as this structure forms the foundation of MPEG-21 transactions. For

this reason, work focussed on the design of an alternative Digital Item Representation in XML of that same DID Model structure; this allows Digital Items to be expressed in a protected, but still transactable form.

The solution proposed defines a separate set of protected elements which can be used in a DID document in place of DIDL equivalents and at any point in the Digital Item hierarchy. Thus an equivalent IPMP DIDL element is defined for each DIDL element that corresponds to an entity in the DID Model (e.g. *Resource* or *Item*). To protect an existing section of a Digital Item hierarchy expressed in DIDL the XML section is encapsulated in the equivalent IPMP DIDL element, which is then placed back into the Digital Item hierarchy in place of the original DIDL element. Figure 2 shows a DIDL *Item* being protected in an IPMP DIDL *Item*.

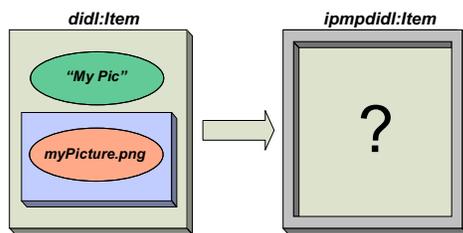


Figure 2: DIDL encapsulation in IPMP DIDL

The key advantage of this method over traditional protection technologies, such as XML encryption, is that an IPMP DIDL representation of a Digital Item remains structurally valid as a transactable Digital Item. This method has been realized in schemas available at <http://www.whisper.elec.uow.edu.au/MPEG21/>. The design process for these schemas is described below.

4. Schema design for IPMP DIDL

For a Digital Item author to protect a specific part of the Digital Item structure by encapsulating it in IPMP DIDL, IPMP DIDL elements must be interchangeable with DIDL equivalents within a DID document. This concept is illustrated in Figure 3, demonstrating how an *Item* within a *Container* may be represented as either DIDL (left) or IPMP DIDL (right).

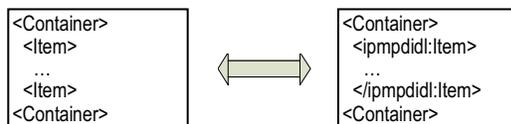


Figure 3: Element interchangeability

For the above scenario to be possible, IPMP DIDL elements must, according to the rules of XML schema,

be in the same *substitution group* as their DIDL equivalents. XML schema substitution holds some parallels with the object-oriented concept of inheritance, and thus the substitutability of element A for element B may only be declared when A is an extension of B. The DIDL, however, was not originally designed with such extensibility in mind, and some mechanism for realising element substitutability was necessary. The authors devised and appraised three mechanisms to address this need.

4.1. Extend and Substitute

This mechanism realized IPMP DIDL elements as XML extensions (derivations) of the DIDL equivalents, inheriting their characteristics and adding in IPMP-specific structure, as shown in Figure 4.

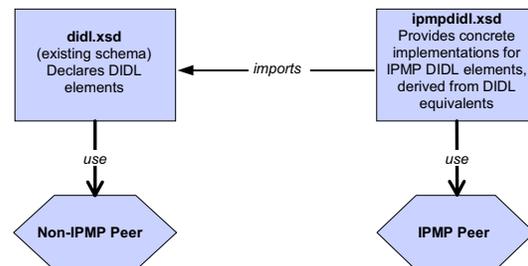


Figure 4: Extend and Substitute mechanism

By virtue of the direct extension from DIDL, this mechanism allowed IPMP DIDL elements to be declared as substitutable for DIDL. However DIDL elements were not originally designed with extension in mind, and may include DIDL-specific mandatory children requirements (for example, *didl:Component* requires at least one *didl:Resource* or a *didl:Reference* child). Thus any IPMP DIDL element which extends these elements also inherits the requirement for these mandatory children, and must contain meaningless ‘dummy’ children to fulfil schema validity.

4.2. Separate schema

An alternative mechanism provided duplicated DIDL schema definitions within an independent IPMP+DIDL schema. In these duplicated definitions, the compulsory child restrictions noted in 4.1 could be removed, avoiding the need for dummy child elements. However this mechanism does not express any interrelationship between DIDL and IPMP DIDL as two expressions of the same DID Model, and requires duplicate definitions in the DIDL and IPMP DIDL schemas to be maintained in parallel. Clearly these are distinct drawbacks for standard schemas where synchronising changes would be necessary.

4.3. Abstract derivation

This third, most innovative solution recognizes that DIDL and IPMP DIDL are both Representations of the DID Model and possess a defined interrelationship, and uses abstract elements to capture the shared semantic. The schema structure is shown in Figure 5.

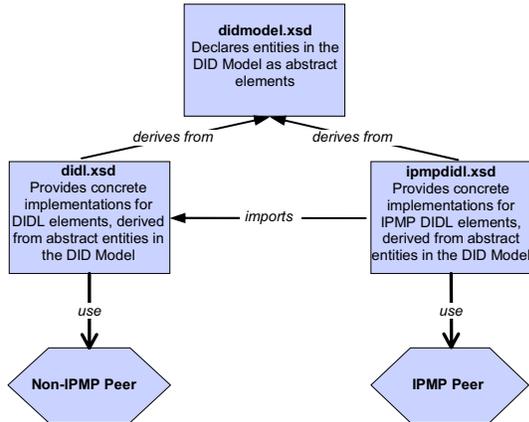


Figure 5: Abstract derivation mechanism

In this mechanism, a parent schema didmodel.xsd represents the DID Model with abstract elements defined to represent each of the DID Model entities (*Container*, *Item*, etc.) such as is shown in Figure 6.

```
<element name="Item" type="didmodel:ItemType" abstract="true">
<complexType name="ItemType">
<complexContent>
<extension base="didmodel:DIDBaseType"/>
</complexContent>
</complexType>
```

Figure 6: didmodel.xsd abstract element example

Two separate schemas define DIDL and IPMP DIDL elements, derived from the parent DID Model elements and with structure appropriate to each Representation, and place them in substitution groups with the parent. Where DIDL elements have child elements, these are declared in terms of the abstract elements. This is shown in Figure 7 and Figure 8.

```
<element name="Item" type="ipmpdidl:ItemType"
substitutionGroup="didmodel:Item"/>
<complexType name="ItemType">
<complexContent>
<extension base="didmodel:ItemType">
...
</extension>
</complexContent>
</complexType>
```

Figure 7: ipmpdidl.xsd element example

```
<xsd:element name="Item" type="didl:ItemType"
substitutionGroup="didmodel:Item"/>
<xsd:complexType name="ItemType">
<xsd:complexContent>
<xsd:extension base="didmodel:ItemType">
...
<xsd:element ref="didmodel:Item"/>
...
</xsd:extension>
</xsd:complexContent>
</xsd:complexType>
```

Figure 8: didl.xsd element example

4.4. Evaluation

The strengths and weaknesses of each mechanism approach were examined, as shown in Table 1.

Table 1: Evaluation of schema mechanisms

Mechanism \ Criterion	Extend and Substitute	Separate schema	Abstract Derivation
IPMP DIDL substitutable for DIDL	✓	✓	✓
No mandatory children on IPMP DIDL	✗	✓	✓
No duplicate definitions requiring synchronization	✓	✗	✓

The authors selected the abstract derivation mechanism as the most flexible means to facilitate DIDL and IPMP DIDL element interchangeability within a protected DID document, allowing DIDL and IPMP DIDL to be different, schematically valid Representations of the DID Model.

5. Structure of IPMP DIDL elements

Once the substitution of IPMP DIDL elements for DIDL equivalents was resolved, the second challenge was the design of the internal structure for these IPMP DIDL elements. Since these elements encapsulate protected DIDL structure alongside relevant information about the protection, the structure was implemented as shown in Figure 9.

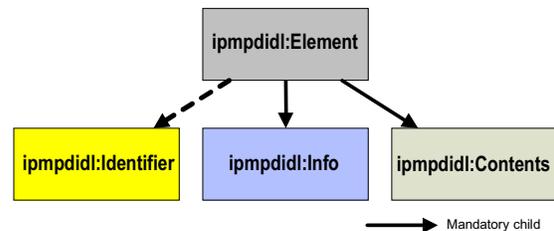


Figure 9: Structure of IPMP DIDL elements

Each of the sub-elements constituting this structure is considered in more detail below.

- *Identifier*: Contains an identifier from an appropriate identification scheme (such as DII) which may be used, for example, when a REL Grant needs to refer to the protected content about which it expresses rights.
- *Info*: Contains expression of mechanisms and licenses involved in the protection of and access to content. This element may link to an existing DRM.
- *Contents*: Contains the governed DIDL structure or asset itself, possibly with encryption, watermarking or other protection tools applied.

Using this three-element structure facilitates the encapsulation and protection of DIDL structure in IPMP DIDL elements with structure as shown in Figure 10.

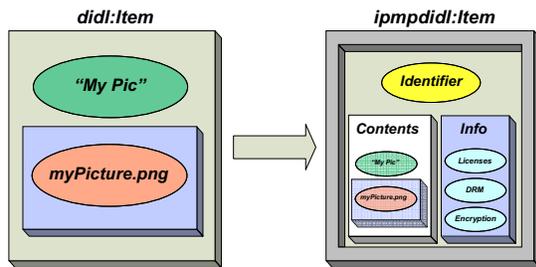


Figure 10: DIDL encapsulation in IPMP DIDL

For particularly sensitive Digital Item contents, the ipmpdidl:Contents may be encrypted or otherwise protected, with a tool described in ipmpdidl:Info. In this case the structure and contents of ipmpdidl:Contents will not be visible, as shown in Figure 11.



Figure 11: Digital Item structure encryption

6. Implementation

Following the design of schemas according to the mechanisms described above, the authors sought to confirm the feasibility of the IPMP DIDL thus defined through the implementation of a prototype MPEG-21 Peer. This prototype was developed as a Java-based mobile phone application, subject to the strict memory

and processing limitations of the MIDP 2.0 Profile of Java 2 Mobile Edition. This mobile Peer was successfully implemented, and parses protected Digital Items according to the IPMP DIDL schema. It also incorporates other IPMP and REL technology to demonstrate the unlocking of protected Digital Item structure according to associated information about the protection mechanisms, and contingent on the validity of associated digital rights expressions.

This implementation confirmed the usefulness of the IPMP DIDL in representing and transacting Digital Items in protected form even on limited platforms. As a result the IPMP DIDL has been adopted into the MPEG-21 Part 4: IPMP Components standard.

7. Conclusion

This paper has described the realization of IPMP DIDL as a protected Representation of the MPEG-21 DID Model. The work has contributed a complete schema solution that facilitates the expression and processing of this protected Representation, and demonstrated its usefulness in an IPMP-enabled MPEG-21 Peer. As a result, Digital Items may include protected structure and information about that protection, allowing Digital Item authors to leverage existing DRM and REL technology. The IPMP DIDL is a simple yet innovative solution that maintains the concept, structure and transactability of the Digital Item while significantly increasing its usefulness in a DRM-hungry multimedia world.

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