——————————— **A R T I C L E S** ———————————

Using MPEG-21 DIDL to Represent Complex Digital Objects in the Los Alamos National Laboratory Digital Library

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Abstract

Various XML-based approaches aimed at representing complex digital objects have emerged over the last several years. Approaches that are of specific relevance to the Digital Library community include the Metadata Encoding and Transmission Standard (METS), the IMS Content Packaging XML Binding, the Sharable Content Object Reference Model (SCORM), and the XML packaging approach developed by CCSDS Panel 2. The MPEG-21 Digital Item Declaration Language (DIDL) is another XML-packaging specification that, so far, has received little attention in the Digital Library community. This article gives a brief insight into the MPEG-21 standardization effort, and indicates its potential relevance to the Digital Library community. It also highlights major characteristics of DIDL, and details research conducted at the Research Library of the Los Alamos National Laboratory (LANL) into the applicability of DIDL for the representation of complex objects in the LANL repository. The positive outcome of this research has led to a decision to make DIDL-conformant documents the unit of storage in the LANL repository, and suggests that DIDL could also be a valuable building block for other Digital Library projects.

1. Introduction

Digital Libraries have reached a point where acceptable architectures must accommodate objects that aggregate datastreams of a wide variety of media-types, and must allow for the association of secondary data – including metadata supporting discovery, digital preservation and rights management – with those datastreams. Also, the notion of the – static or dynamic – association of dissemination capabilities with such objects must be entertained by contemporary Digital Library architectures.

The seminal Kahn/Wilensky framework [10] refers to a digital object as the basic entity for storing, managing and disseminating information in a Digital Library architecture. The framework defines a digital object as more than just a set of bits: it should be regarded a data structure with a unique persistent identifier that, apart from the

datastream(s), holds secondary information about the contained datastream(s). It comes as no surprise that, since the publication of the Kahn/Wilensky framework, various approaches have emerged from different communities aimed at representing digital objects. Approaches that are of specific relevance to the Digital Library community include the Metadata Encoding and Transmission Standard (METS) [30], the IMS Content Packaging XML Binding [8], the Sharable Content Object Reference Model (SCORM) [1] and the XML packaging approach developed by CCSDS Panel 2 [5]. All these efforts specify an XML-based data structure for digital objects.

Through collaboration with the Multimedia Lab of Ghent University [note 6], the authors became aware of another XML-based packaging format that emerged from the ongoing MPEG-21 standardization effort [3]. The MPEG-21 work has received little attention in the Digital Library community, possibly because specifications are not freely available online, as a result of an ISO strategy. MPEG Standards must be purchased from ISO [note 1], while reference software is made publicly available. Digging deeper into MPEG-21 documentation, the authors became increasingly intrigued, and decided to actively explore the applicability of MPEG-21 concepts in the context of ongoing Digital Library repository work at the Research Library of the Los Alamos National Laboratory (LANL). The main motivations for this decision can be summarized as follows:

- **Potential impact of MPEG-21** – MPEG [note 2] is an ISO/IEC Committee, and provides a mechanism to feed research results into an ISO standard. So far, several MPEG Standards have had a significant impact on the multimedia landscape. For example, MPEG has produced the MPEG-1 and MPEG-2 Standards, on which formats such as Video CD, MP3, Digital Television, and DVD are based. It is likely that the MPEG-21 Standard will have a similar impact.

- **MPEG-21's modular architecture** – The vision for MPEG-21 is 'to define a normative open framework for multimedia delivery and consumption for use by all the players in the delivery and consumption chain'. The envisioned framework covers the entire media content delivery chain, encompassing content creation, adaptation, and dissemination. The unfinished Standard consists of 12 high-level, modular Parts, including:
  - MPEG-21 Part 2 – Digital Item Declaration Language (henceforth referred to as DIDL), detailing the representation of complex digital objects [15]
  - MPEG-21 Part 3 – Digital Item Identification Language (henceforth referred to as DII), detailing the identification of complex digital objects and their contained entities [17]
  - MPEG-21 Part 4 – Intellectual Property Management and Protection (henceforth referred to as IPMP), detailing a framework to enforce rights expressions pertaining to complex digital objects [21].
  - MPEG-21 Part 5 – Rights Expression Language (henceforth referred to as REL), detailing a language to express rights pertaining to complex digital objects and their contained entities [22]
  - MPEG-21 Part 7 – Digital Item Adaptation (henceforth referred to as DIA), detailing the adaptation and transcoding of datastreams based on contextual information such as agent capabilities, network characteristics and user preferences [18]
  - MPEG-21 Part 10 – Digital Item Processing (henceforth referred to as DIP), detailing the association of processing methods with complex digital objects and their contained entities [19, 20]

- **Ability to accommodate any media type and genre** – Although MPEG-21 originates in a community that focuses on motion picture, audio, and video, the MPEG-21 framework can accommodate any kind of complex digital objects including electronic texts, electronic journals, scientific datasets, etc.

- **Applicability to Digital Libraries** – There is a clear overlap between the problem domain addressed by the MPEG-21 effort, and ongoing efforts regarding the representation, storage, and dissemination of complex digital objects in the Digital Library community. For example, MPEG-21 DIDL and DII directly relate to the aforementioned XML-based packaging approaches. Also, MPEG-21 DIP and DIA reveal a remarkable parallel with sophisticated architectures that emerged from the Digital Library community [23], specifically FEDORA [7, 26, 29] and SODA [12, 24]. And, recently, the usage of MPEG-21 REL has been proposed in the ISO/IEC SC36 E-Learning standardization effort [9].

This article describes the results of research into the applicability of the MPEG-21 DIDL and DII for packaging complex digital objects to be submitted to, stored in, and disseminated from the repository of the LANL Research Library. A future article will report on the repository architecture used to store and disseminate the complex digital

objects, which builds on DIDL [note 3], the OAI-PMH [11], the NISO OpenURL Framework [25] and concepts from the MPEG-21 DIP.

## 2. DIDL: MPEG-21 Digital Item Declaration Language

In the MPEG-21 Framework, complex digital objects are declared using the Digital Item Declaration Language (DIDL). DIDL introduces a set of abstract concepts that, together, form a well-defined data model for complex digital objects [note 4]. Based on those abstract concepts, DIDL defines a W3C XML Schema [note 5] that provides broad flexibility and extensibility for the actual representation of compliant complex digital objects. In the remainder of this article, a complex digital object represented according to the DIDL Schema will be referred to as a Digital Item Declaration, or DID. Core characteristics of the DIDL data model, the DIDL XML Schema, and DIDs are described in the remainder of this section.

2.1 Data Model

This section provides an informal, and simplified explanation of the DIDL data model. The DIDL data model recognizes the following entities, which are visually represented in Figure 1:

- A *Container* is a grouping of *Containers* and/or *Items*. In the XML representation, a *Container* is accommodated by the `didl:Container` element ({1} in Figure 1 and Appendix A)
- An *Item* is a grouping of *Items* and/or *Components*. In the XML representation, an *Item* is accommodated by the `didl:Item` element ({2} in Figure 1 and Appendix A)
- A *Component* is a grouping of *Resources*. Multiple *Resources* in the same *Component* are considered equivalent and consequently an agent may use any one of them. In the XML representation, a *Component* is accommodated by the `didl:Component` element ({3} in Figure 1 and Appendix A)
- A *Resource* is an individual datastream. In the XML Schema, a *Resource* is accommodated by the `didl:Resource` element ({4} in Figure 1 and Appendix A)
- Secondary information pertaining to a *Container*, an *Item*, or a *Component* can be conveyed by means of a *Descriptor*. In the XML representation, a *Descriptor* is accommodated by the `didl:Descriptor` element ({5} in Figure 1 and Appendix A). By definition, a `didl:Descriptor` is associated with its parent element in the XML representation. For example, a `didl:Descriptor` provided as a child element of a `didl:Component` is associated with that `didl:Component`.

The DIDL specification provides abstract definitions for each of the aforementioned entities and their interrelations. Those definitions can hardly be used as a cookbook for representing a collection of related datastreams as a DID; they actually allow for various approaches to do so. For example, when representing an audio album using DIDL, one could create a DID which has an *Item* per audio track, or a DID with a single *Item* containing multiple *Components*, etc. In many cases, the actual choice for one representation or another will be inspired by the requirements of the target application. Figure 1 shows the structure of a DID that is conformant with the DIDL specification. The figure clearly illustrates the elaborate nesting capabilities of DIDL.
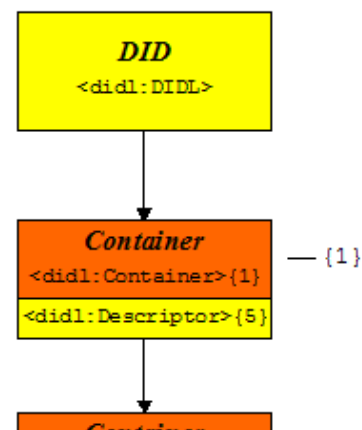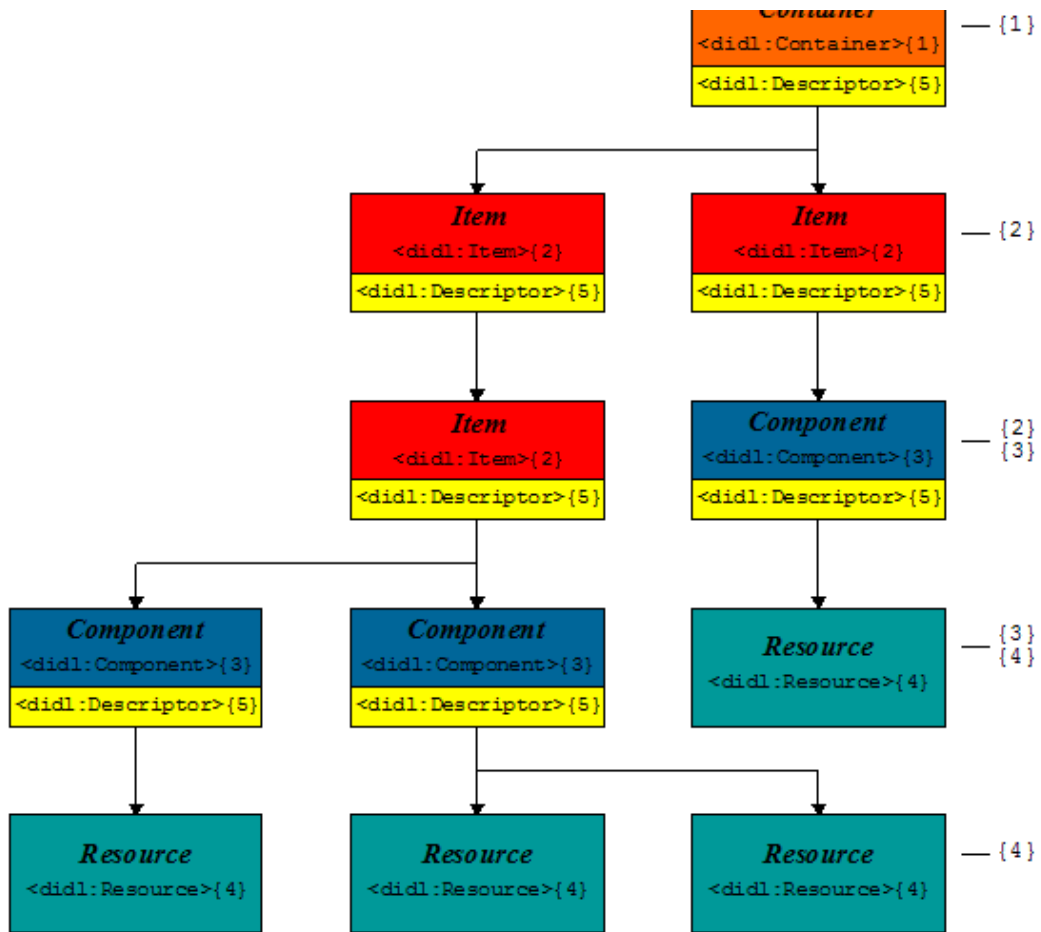
Figure 1: Example of a DID structure conformant with the DIDL specification

2.2 Providing datastreams and secondary data

Table 1 shows the techniques available in DIDL to deliver datastreams and secondary information. As can be seen, DIDL allows these to be contained in a DID – By Value – or to be pointed at from within a DID – By Reference. Table 1 also shows how the nature of the datastreams and secondary information relates to the way in which they are provided in a DID. The triangles in Table 1 indicate functionality that most likely will become available as a result of amendments proposed by the authors and their colleagues from Ghent University. The MPEG Committee has recently approved these amendments [2] as a Working Draft for the DIDL Extension specification [16].

Table 1: By Value and By Reference provision of datastreams and
secondary information in a DID

2.3 More about Descriptors

Descriptors provide an extensible mechanism to convey secondary information about entities of the DIDL data model. For example, in order to associate – say – an identifier with an ***Item***, a `didl:Descriptor` containing the identifier can be created as a child element of the `didl:Item` element.

As will be shown in the remainder of this section, the MPEG-21 framework itself defines ways to use ***Descriptors*** as a means to convey identification information, rights information, processing information, etc. But, to facilitate the provision of community-specific or application-specific information, ***Descriptors*** may also be defined by third parties. In order to do so, typically, an XML Schema with an associated XML Namespace is created to contain elements and attributes required to address specific needs. This approach is illustrated in Section 3.3 by detailing the ***Descriptors*** defined at LANL.

2.3.1 DII: Using a Descriptor for Identification

MPEG-21 Digital Item Identification (DII) specifies the usage of ***Descriptors*** for the identification of DIDs and their contained entities. It introduces a DII XML Namespace with elements that can be used to associate identifiers and/or types with ***Containers***, ***Items***, ***Components*** and ***Descriptors***. For example, Table 2 shows the use of the `dii:Identifier` element to associate the URI **"urn:isbn:0-395-36341-1"** with a `didl:Item`. Through the introduction of a special Part dedicated to the identification of entities, MPEG-21 recognizes the importance of identifiers in network-based applications. Some packaging approaches, including METS, address identification in less fundamental and less extensible manners.

```
<didl:Item>
    <didl:Descriptor>
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                urn:isbn:0-395-36341-1</dii:Identifier>
        </didl:Statement>
    </didl:Descriptor>
    …
</didl:Item>
```

Table 2: `dii:Identifier` (***Item*** level)

2.3.2 Using Descriptors to convey processing information

MPEG-21 Digital Item Processing (DIP) specifies an architecture pertaining to the dissemination of DIDs. This Part – yet to be standardized – introduces a special type of ***Item*** named ***Processing Item***, which may be used to specify the methods by which a DID and its contained entities can be processed. ***Items*** are identified as ***Processing Items*** by including a ***Descriptor*** containing the `dii:Type` element from the DII XML Namespace, and by assigning it the reserved value "**urn:mpeg:mpeg21:2002:01-DIP-NS:PI**". It is worthwhile noting that the MPEG-21 ***Processing Item*** concept is closely related to Fedora's "behavior" concept [7, 26, 29]. A ***Processing Item*** is physically contained in the same DID as the entity of the data model with which it is associated. For example, a ***Processing Item*** can be associated with a ***Container***, an ***Item***, or a ***Component***. Because DIP remains to be standardized, a more detailed description of ***Processing Items*** is out of the scope of this article. It suffices to say that, typically, a ***Processing Item*** either contains or points at code that can be used to process an entity of a DID.

An entity of the data model can be accorded a `dip:ObjectType` element from the DIP XML Namespace. A

dip:ObjectType associated in this manner with an entity can be used as a key to actual bind the entity to a *Processing Item*. As a matter of fact, this approach conveys that the processing method specified by the *Processing Item* uses as argument the entity of the DID for which the content of the dip:ObjectType element is the same as the content of the *Processing Item*'s dip:Argument. It is helpful to think of the dip:ObjectType as a 'link' between an entity and a *Processing Item*, not as an indication of the 'genre' of an entity.

Table 3 shows an *Item* associated with a *Processing Item* by means of the value '**urn:my:Argument**'. That value is used as the content of both the dip:ObjectType element of the *Item*, and the dip:Argument element of the *Processing Item*. It is also shown that the *Processing Item* is assigned the identifier '**urn:bar:a333766936**' through the use of the dii:Identifier element from the DII XML Namespace. The DIP specification allows entities to have more than one dip:ObjectType. Also, a *Processing Item* can bind to more than one entity by using multiple dip:Argument elements, each of which connects via the dip:ObjectType to the entities.

```xml
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
    <didl:Container>
        …
        <!-- Item containing content -->
        <didl:Item>
            …
            <!-- ObjectType of Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dip:ObjectType xmlns:dip="urn:mpeg:mpeg21:2002:01-DIP-NS">
                        urn:my:Argument</dip:ObjectType>
                </didl:Statement>
            </didl:Descriptor>
            …
        </didl:Item>
        …
        <!-- Processing Item -->
        <didl:Item>
            <!-- Qualification of the Item as Processing Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dii:Type xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                        urn:mpeg:mpeg21:2002:01-DIP-NS:PI</dii:Type>
                </didl:Statement>
            </didl:Descriptor>
            <!-Processing Item identification -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                        urn:bar:a333766936</dii:Identifier>
                </didl:Statement>
            </didl:Descriptor>
            <!-- Actual processing method -->
            <didl:Component>
                <didl:Descriptor>
                    <!-- Argument of processing method -->
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <dip:Argument xmlns:dip="urn:mpeg:mpeg21:2002:01-DIP-NS">
                            urn:my:Argument</dip:Argument>
                    </didl:Statement>
                </didl:Descriptor>
                <!-- Actual code for processing method-->
                <didl:Resource mimeType="…">
                    …Link to processing code…</didl:Resource>
            </didl:Component>
        </didl:Item>
    </didl:Container>
```

```
</didl:DIDL>
```

Table 3: *Processing Item* and `dip:ObjectType` *Descriptor* for the associated *Item*

2.3.3   Using Descriptors to convey rights expressions

MPEG-21 Rights Expression Language (REL) specifies the usage of *Descriptors* to associate rights expressions with DIDs and their contained entities. This is achieved through the introduction of a language inspired by XrML [6] with elements and attributes in a REL XML Namespace. Table 4 shows the use of the `r:license` element to associate simple copyright information with a `didl:Item`. MPEG-21 Intellectual Property Management and Protection (IPMP) will provide tools to enforce rights expressions declared by means of REL.

```
<didl:Item>
    …
    <didl:Descriptor>
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <r:license xmlns:r="urn:mpeg:mpeg21:2003:01-REL-R-NS">
                <!-- optionally, specific rights can be added here.-->
                <r:otherInfo>
                    <dc:rights xmlns:dc="http://purl.org/dc/elements/1.1/">
                    Copyright 2003; American Physical Society</dc:rights>
                </r:otherInfo>
            </r:license>
        </didl:Statement>
    </didl:Descriptor>
    …
</didl:Item>
```

Table 4: A simple Rights Expression

3   Usage of MPEG-21 DIDL at the LANL Research Library

When researching the usage of the MPEG-21 Digital Item Declaration Language to represent complex digital objects in the repository at the LANL Research Library, two major questions emerged:

- How to map the – related – datastreams to be contained in a complex object of the LANL repository to the DIDL data model
- How to use *Descriptors* to meet the design goals of the repository and its associated applications

Both questions will be addressed in the remainder of this section, by providing an insight into the major design choices that were made when implementing DIDL at the LANL Research Library. The described design choices result in a DID *profile*, which has formally been expressed as a Schematron schema [note 3]. DIDs conformant to the design choices must be valid according to the DIDL XML Schema as well as according to this Schematron schema.

In the remainder of this article, XML excerpts of a LANL DID are provided to illustrate the main design choices that were made. A full representation of the DID from which excerpts are taken is provided in Appendix A. This DID is the DIDL-based representation of a complex object consisting of:

- A LANL technical report, which is a single PDF file with identifier '**urn:bar:99-7537**'.
- Descriptive metadata about the LANL technical report expressed by means of the MARC format. Actually, two versions of the MARC data are provided: the original MARC record, and a MARCXML representation derived from it. The identifier of the MARC record is '**urn:bar:56-8730**'.

3.1   LANL DIDs grow in breadth, not in depth

DIDs at LANL make no use of the extensive nesting capabilities provided by the DIDL data model or the associated XML Schema. All DIDs use a simple 3-level hierarchy *Container* / *Item* / *Component*. As a result, the DIDs cannot grow in depth, but can do so in breadth through the addition of *Items* to a *Container*, *Components* to an *Item*, and *Resources* to a *Component*. Figure 2 illustrates this approach. As will be shown, hierarchical relationships that could be expressed by nesting entities are instead represented by means of a special purpose Descriptor.
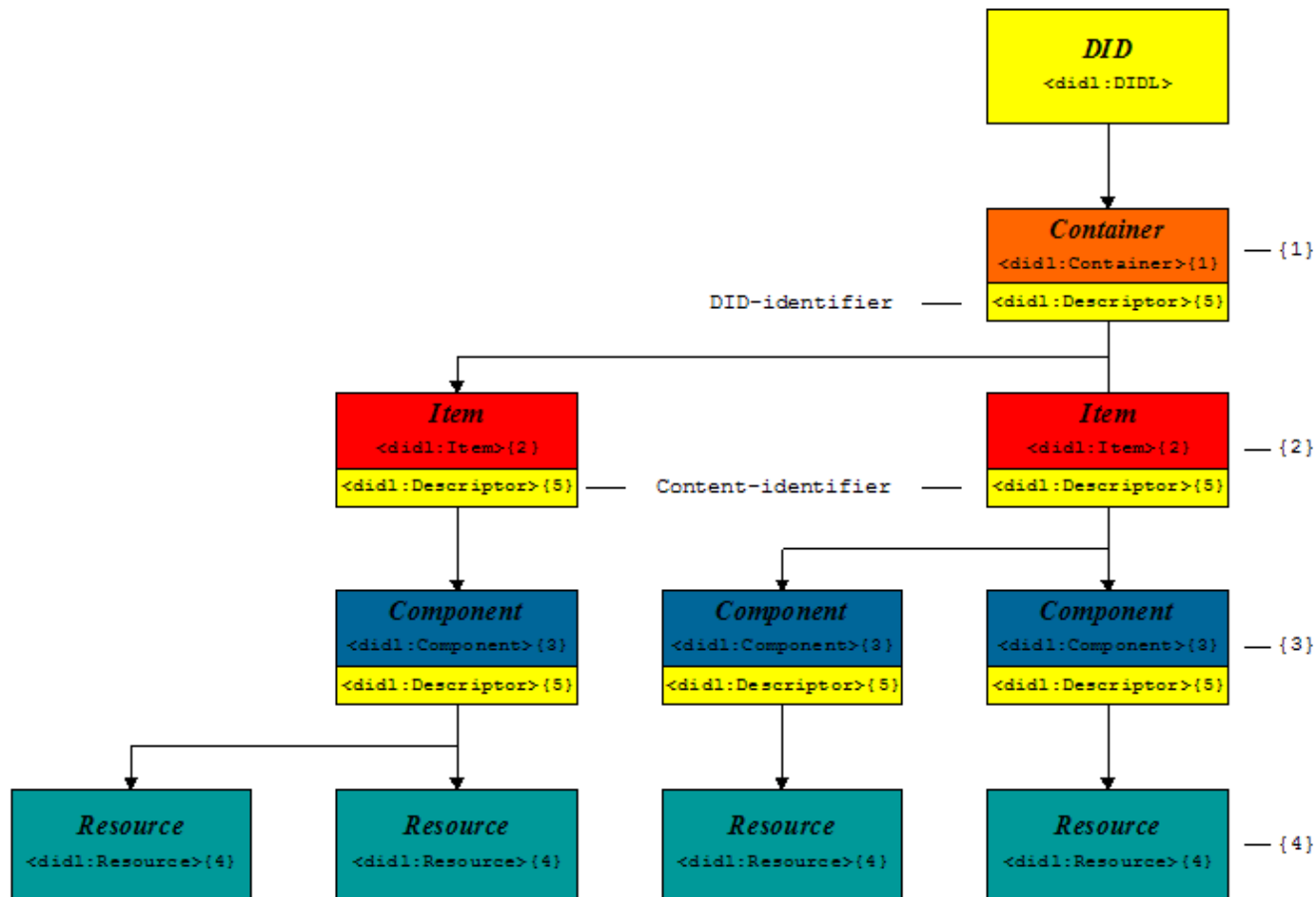

Figure 2: Example of a LANL DID structure following the LANL DIDL *profile*

3.2   All LANL data is created equal

The LANL repository harbors tens of millions of records from abstracting and indexing databases. These metadata records are "stand-alone" in that they do not come with their full-content counterparts. As a result, when embedding such a record in a DID, it can hardly be provided as secondary data because there is no primary datastream to which to attach it. Therefore, it is provided as a datastream in its own right. This approach is generalized to also embed descriptive metadata as an autonomous datastream in a DID when the DID contains both the descriptive metadata and the content it describes. While this might be contrary to the mainstream approach in this respect, a case in its favor can be made. First, descriptive metadata – in many cases expensive to create – should also be the subject of digital preservation, and as a result be treated as a potentially endangered datastream in its own right. Second, as technologies evolve and datastreams of a variety media-types become directly searchable, the special status of descriptive metadata as the sole point of entry to those datastreams might eventually weaken, turning descriptive metadata and datastreams into peers. As will be shown, the relationship between the metadata and the content it describes is represented by means of a special-purpose *Descriptor*.

Table 5 shows a DID that represents the LANL technical report. The *Container* accommodates 2 *Items*. The first

Item contains the MARC metadata about the LANL technical report. This *Item* contains two *Components*: the second has a *Resource* that is the - base64 encoded - original MARC record, the first has a *Resource* that is a MARCXML version of the original MARC record. The second *Item* contains the technical report provided by means of two *Resources* in a single *Component*, indicating the equivalence of both *Resources*. In the first *Resource*, the PDF is provided By Value, and hence is base64-encoded. For illustrative purposes, the PDF is also provided By Reference in a second *Resource* through the inclusion of a reference to its network-location.

```xml
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
    <didl:Container>
        <!-- DID-identifier -->
        <didl:Descriptor>
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                    urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b</dii:Identifier>
            </didl:Statement>
        </didl:Descriptor>
        …
        <!-- Item accommodating descriptive metadata about technical report -->
        <didl:Item>
            …
            <!-- Content-identifier of descriptive metadata -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                        urn:bar:56-8730</dii:Identifier>
                </didl:Statement>
            </didl:Descriptor>
            …
            <didl:Component>
                …
                <didl:Resource mimeType="text/xml; charset=UTF-8">
                    <record xmlns="http://www.loc.gov/MARC21/slim">
                        <leader>01142cam 2200301 a 4500</leader>
                        <controlfield tag="005">19930521155141.9</controlfield>
                        …
                </didl:Resource>
            </didl:Component>
            <didl:Component>
                …
                <didl:Resource encoding="base64" mimeType="application/marc">
                    j0iMS4wIiBlbmNvZGluZz0iVVRGLTgiPz4NCjxjb2xsZWN0aW9uIHhtbG5zSJodH
                    RwOi8vd3d3LmxvYy5nb3YvTUFSQzIxL3NsaW0iPg0KICA8cmVjb3JkPg0KICAgID
                    PD94bWwgdmVyc2lvb…
                </didl:Resource>
            </didl:Component>
        </didl:Item>
        <!-- Item accommodating technical report -->
        <didl:Item>
            <!-- Content-identifier of technical report -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                        urn:bar:99-6537</dii:Identifier>
                </didl:Statement>
            </didl:Descriptor>
            …
            <didl:Component>
                …
                <didl:Resource encoding="base64" mimeType="application/pdf">
                    PSJjIIj5jMTk5My48L3N1YmZpZWxkPg0KICAgIDw9uIHhtbG5zSJodHgKICAgIDxk
                    dGFnPSIzMDAiIGluZDE9IiAiIGluZDI9IiAiPg0KICAgICAgPHN1YmZpZWxkIGNv

```
                    cmVzdG9yZWQgdG8g…
                </didl:Resource>
                <didl:Resource mimeType="application/pdf"
                    ref="http://foo/bar/733902fg992.pdf"/>
            </didl:Component>
        </didl:Item>
    </didl:Container>
 </didl:DIDL>
```

Table 5: A DID representing the LANL technical report

3.3 LANL's usage of Descriptors

3.3.1 Identifiers

In Digital Library applications, identifiers are of utmost importance. Identifiers were at the core of the seminal Kahn/Wilensky Framework [10], and they rightfully received special attention in the OAIS model [28]. Therefore, identifiers became a core element in the design of LANL DIDs, and their implementation is based on MPEG-21 DII:

- Identifiers are mandatory for the identification of the DIDs themselves. These 'DID-identifiers' (see Figure 2) are provided as the content of the `dii:Identifier` element in a `didl:Descriptor` which has the sole `didl:Container` element of the DID as its parent. These identifiers are dynamically assigned when DIDs are created, and they are UUID URNs [13].
- To map datastreams to the DIDL data model, a strong relationship has been defined between *Items* and identifiers:
  - When a single datastream has an identifier, it must be treated as an *Item*.
  - When multiple datastreams share an identifier, their combination must be treated as an *Item*.
  - All *Items* must have an identifier.

  These 'Content-identifiers' (see Figure 2) are provided as the content of the `dii:Identifier` element, which, in this case, is contained in a `didl:Descriptor` child element of the `didl:Item` element. Multiple 'Content-identifiers' for a single Item can exist. As is the case with 'DID-identifiers', 'Content-identifiers' can be dynamically assigned when DIDs are created. Also, at LANL, 'Content-identifiers' are in many cases inferred from the data to be contained in the *Item*. For example, when a record from the PubMed database is included in a DID, it receives a 'Content-identifier' such as 'info:pmid/14577066', where 14577066 is the unique PubMed number for the record, and 'info' is a proposed URI scheme [31].

This identifier-centric approach to XML-packaging of datastreams is somehow in contrast with the hierarchy-centric perspective of approaches such as METS and IMS, in which structural metadata are at the core of the document models (cf. the mandatory structural map in METS). As will be shown, in LANL DIDs, structural and relational metadata is represented by means of a special-purpose ***Descriptor***.

Table 5 shows the use of both the 'DID-identifiers' and 'Content-identifiers'. A `dii:Identifier` element associates the 'DID-identifier' "**urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b**" with the `didl:Container` element. And, a `dii:Identifier` is used to attach the 'Content-identifiers' '**urn:bar:56-8730**' and '**urn:bar:99-6537**' with the MARC record and the technical report, respectively.

3.3.2 Processing Items and their 'Placeholders'

In LANL, DIDs will be used as a mean to store and disseminate complex digital objects. The authors felt a general level of discomfort with embedding ***Processing Items*** - which express the methods that can be used to process contained entities – in stored DIDL objects. This discomfort is related to the anticipated need to frequently update the content of ***Processing Items*** as new processing methods emerge, or existing ones are updated. This anticipated need to regularly "touch" stored DIDs is a poor fit with the rather static nature of the contained content at LANL,

and with the OAIS-inspired strategy to create new DIDs – instead of updating existing ones – when some form of editing has been performed.

As a result, it was decided not to embed *Processing Items* in DIDs, but instead to embed 'Placeholders' for *Processing Items*. When the dissemination of a stored DID is requested, the contained 'Placeholders' will dynamically be exchanged for actual processing-related information. The 'Placeholder' concept is implemented by means of a `didl:Descriptor` that contains a `diph:PlaceHolder` element from a self-defined XML Namespace. It can be attached at the `didl:Container`, `didl:Item` and `didl:Component` level. When a stored DID is disseminated, the following is achieved by looking up the content of each embedded `diph:PlaceHolder` element in a special-purpose registry:

- Based on correspondences expressed in the registry, a `diph:PlaceHolder` element is replaced by one or more `dip:ObjectType` elements
- Based on registry-information, *Processing Items* are added to the DID, and connected to the inserted `dip:ObjectType` elements in the manner described in [Section 2.3.2](#).

The result of this approach is a dynamic way of binding stored DIDs to specific dissemination methods. These methods, however, are not hard-coded into the DIDs, and hence they can easily evolve over time. The 'Placeholders' can be regarded as a flexible bridge between an Archival Information Package and a Dissemination Information Package.

[Table 6](#) shows the use of the `diph:PlaceHolder` element to include 'Placeholders' at the level of the *Container*, *Item* and datastreams. [Table 7](#) shows the result of replacing the `diph:PlaceHolder` element of one of the *Components* with a corresponding `dip:ObjectType` and *Processing Item*. The correspondence between a `diph:PlaceHolder` element, the `dip:ObjectType` element, and the *Processing Items* is retrieved from the special-purpose registry. It should be noted here that one `diph:PlaceHolder` element may be replaced by multiple `dip:ObjectType` elements.

```xml
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
    <didl:Container>
        …
        <!-- PlaceHolder of Container -->
        <didl:Descriptor>
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <diph:PlaceHolder
                    xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                    urn:foo:TechReport</diph:PlaceHolder>
            </didl:Statement>
        </didl:Descriptor>
        …
        <!-- Item containing MARC content -->
        <didl:Item>
            …
            <!-- PlaceHolder of Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <diph:PlaceHolder
                        xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                        urn:foo:Metadata</diph:PlaceHolder>
                </didl:Statement>
            </didl:Descriptor>
            …
            <didl:Component>
                <!-- PlaceHolder of datastream -->
                <!-- Table 7 shows the result after replacement of this PlaceHolder
 -->
                <didl:Descriptor>
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
```

```
                        <diph:PlaceHolder

xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                            urn:foo:Metadata:MARC/XML</diph:PlaceHolder>
                    </didl:Statement>
                </didl:Descriptor>
                …
            </didl:Component>
        </didl:Item>
        <didl:Item>
            …
            <!-- PlaceHolder of Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <diph:PlaceHolder
                        xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                        urn:foo:FullReport</diph:PlaceHolder>
                </didl:Statement>
            </didl:Descriptor>
            …
        </didl:Item>
    </didl:Container>
</didl:DIDL>
```

Table 6: Placeholders implemented using `diph:PlaceHolder`. Table 7 shows the result after replacement of the highlighted section

```
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
    <didl:Container>
        …
        <!-- Item containing MARC content -->
        <didl:Item>
            …
            <didl:Component>
                …
                <!-- ObjectType of Component as retrieved from registry -->
                <didl:Descriptor>
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <dip:ObjectType xmlns:dip="urn:mpeg:mpeg21:2002:01-DIP-NS">
                            urn:foo:Argument1</dip:ObjectType>
                    </didl:Statement>
                </didl:Descriptor>
                …
            <didl:Component>
                …
        </didl:Item>
        …
        <!-- Processing Item as retrieved from registry -->
        <didl:Item>
            <!-- Qualification of the Item as Processing Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <dii:Type xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                        urn:mpeg:mpeg21:2002:01-DIP-NS:PI</dii:Type>
                </didl:Statement>
            </didl:Descriptor>
            <!-- identifier Processing Item -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
```

```xml
            <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                urn:bar:a766654336</dii:Identifier>
        </didl:Statement>
    </didl:Descriptor>
      <!-- Actual processing method -->
    <didl:Component>
        <didl:Descriptor>
            <!-- Argument of processing method -->
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <dip:Argument xmlns:dip="urn:mpeg:mpeg21:2002:01-DIP-NS">
                    urn:foo:Argument1</dip:Argument>
            </didl:Statement>
        </didl:Descriptor>
        <!-- Actual code that can be used to process the MARC/XML -->
        <didl:Resource mimeType="…">
        …Link to processing code…</didl:Resource>
    </didl:Component>
        </didl:Item>
    </didl:Container>
 </didl:DIDL>
```

Table 7: *Processing Item* and `dip:ObjectType` *Descriptor* for the associated *Item*, after replacement of the highlighted section of Table 6

3.3.3 Relationships

A special-purpose *Descriptor* is introduced to express relationships between entities contained in DIDs. This *Descriptor* is based on a self-defined Digital Item Relations (DIR) XML Namespace, which contains RDF Statements expressing relations such as "isDerivationOf", "isPartOf", "isTranslationOf", "isDescriptiveMetadataOf", etc.

The core characteristics of the relationship approach are:

- RDF [34] is used as the language to express the entities involved in a relationship and the nature thereof.
- The RDF statements are based on a vocabulary of relationships. This vocabulary remains to be defined, and terms will probably be created when required. It may be possible to import terms from existing XML Namespaces, such as dcterms [4] and PRISM [27].
- For the identification of resources involved in relationships, the following approach is taken:
  - A DID is identified by means of its DID-identifier
  - An Item and Component are identified by means of an XML fragment identifier - XPointers [33, 35] - expressed relative to the DID. The actual nature of these XPointer expressions is the subject of ongoing research. One approach is to base XPointers on ID-typed elements. IDs are a robust identification method, as they remain valid even after repositioning an element in a document. However, this approach requires the introduction of IDs for every entity involved in a relationship. Another approach is to use XPointers based on the DID structure itself. This approach comes with little initial overhead, but processing XPointers of this type may be more cumbersome than processing ID-based XPointers.
- The following conventions were introduced to include relationship information in a DID:
  - Relationships between *DIDs*, and between a *DID* and resources external to the actual DID are expressed by attaching a DIR *Descriptor* to the corresponding `didl:Container` element.
  - Relationships between an *Item* and other *Items* contained in a DID, and between an *Item* and the *Components* within that *Item*, and relationships between an *Item* and resources external to the actual DID are expressed by attaching a DIR *Descriptor* to the corresponding `didl:Item` element.
  - Relationships between *Components* within an *Item*, and between *Components* and resources external to the actual DID are expressed by attaching a DIR *Descriptor* to the corresponding `didl:Component` element.

These conventions are inspired by the distinct treatment of Context Information and Representation Information in the OAIS model. The OAIS Model defines Context Information as information that documents the relationships of a Data Object (i.e., the identified digital object) to its environment and how it relates to other Data Objects. Representation Information describes the internal structure (including hierarchies) of the Data Object. As such, it seems that relational information pertaining to the *Items* resorts under the OAIS Context Information, while relational information pertaining to *Resources* resorts under OAIS Representation Information. Pragmatism also played a role in deciding upon these conventions, because - from an application-perspective - it is easier to manipulate *Items* that contain their own relationships as this makes the *Items* self-contained.

Table 8 shows a *Descriptor*, describing the metadata/content relationships between the MARC record and the technical report described by the MARC record. It also shows the relationship between the *Items* and a larger collection. Because these are interrelations between *Items* and relations between *Items* and an external resource, the *Descriptor* is attached to the didl:Item element of the MARC record.

```xml
<didl:Item>
    …
    <!-- Relationships on an Item level -->
    <didl:Descriptor>
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <dir:Relations xmlns:dir="http://library.lanl.gov/2003-11/MPEG-21/DIR">
                <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
                xml:base="urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b">
                <rdf:Description rdf:about="#//didl:Item[1]">
                    <a:isPartOf xmlns:a="http://purl.org/dc/terms/#">
                        <rdf:Description
rdf:about="info:sid/library.lanl.gov:lanl-opac">
                            <b:hasType xmlns:b="http://…/Relations#"
                            rdf:resource="http://…/Relations#Collection"/>
                        </rdf:Description>
                    </a:isPartOf>
                <rdf:Description>
                <rdf:Description rdf:about="#//didl:Item[1]">
                    <b:isDescriptiveMetadataOf xmlns:b="http://…/Relations#"
                    rdf:resource="#//didl:Item[2]"/>
                </rdf:Description>
                </rdf:RDF>
            <dir:Relations>
        </didl:Statement>
    </didl:Descriptor>
    …
</didl:Item>
```

Table 8: *Item* relationships

3.3.4 Creation date

A special-purpose *Descriptor* is introduced to express the datetime of creation of the DID entities contained in DIDs. This *Descriptor* contains a didt:Created element from a self-defined Digital Item DateTime XML Namespace. The date and time values are formatted according to the W3C profile of ISO 8601 [32]

Table 9 shows a didl:Container with a *Descriptor* that conveys the datetime of creation of the *Container* structure, namely '**2003-09-05T21:51:01Z**', and a didl:Item with a *Descriptor* that accommodates the datetime of creation of the *Item* structure, namely '**2003-09-05T18:30:07Z**'. The *Descriptor* is also used to convey the datetime of creation of an actual datastream.

```xml
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
```

```
<didl:Container>
    …
    <!-- Creation-datetime of Container -->
    <didl:Descriptor>
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <didt:Created
                xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                2003-09-05T21:51:01Z</didt:Created>
        </didl:Statement>
    </didl:Descriptor>
    …
    <didl:Item>
        …
        <!-- Creation-datetime of Item -->
        <didl:Descriptor>
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <didt:Created
                    xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                    2003-09-05T18:30:07Z</didt:Created>
            </didl:Statement>
        </didl:Descriptor>
        …
        <didl:Component>
            …
            <!-- Creation-datetime of datastream -->
            <didl:Descriptor>
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <didt:Created
xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                        2002-05-03T14:30:03Z</didt:Created>
                </didl:Statement>
            </didl:Descriptor>
            …
        </didl:Component>
    </didl:Item>
    …
</didl:Container>
</didl:DIDL>
```

Table 9: `didt:Created` at *Container*, *Item* and datastream level

4 Conclusion

This article has described the application of the MPEG-21 Digital Item Declaration Language to represent complex digital objects from the collection at the LANL Research Library. Although the article has not explicitly touched on the matter, the authors hope to have shown that, generally, usage of MPEG-21 DIDL as a complex object document model for Digital Library applications is a feasible, and actually attractive option:

- From a strategic perspective, DIDL is appealing because it is part of the MPEG-21 suite of Standards which is likely to receive strong industry backing. Also, DIDL is part of a broader architecture that is relevant to many communities, including the Digital Library community.
- From a functional perspective, DIDL is attractive because of the flexibility offered by its well-specified data model, and because of the extensibility provided by the *Descriptor* approach. The MPEG-21 Standard itself makes use of those Descriptors to provide a fundamental solution for the identification of entities, to associate processing methods with entities, to express rights related to entities, and to allow for the enforcement of those rights. As has been shown by means of the LANL DIDs, *Descriptors* can be used to meet specific design requirements. At LANL, *Descriptors* have been used to enforce an identifier-centric document model, to implement a dynamic association between entities and processing methods, and to

introduce a novel way to express relationships. More generally, *Descriptors* can be used as a tool to address community-specific interoperability requirements. For example, one of the authors has done initial research regarding the use of DIDL for the representation of complex digital objects for the purpose of digital preservation, using *Descriptors* as a technique to map OAIS metadata categories to the DIDL data model.

DIDs created at LANL are fully compliant with the DIDL specification. Compliance with the LANL DID design is enforced by first validating DIDs against the DIDL XML Schema, and next against a Schematron schema that formalizes the design characteristics of LANL DIDs. The DIDs will be the unit of storage in the LANL repository. Soon ingestion will start, and millions of DIDs will be created. A forthcoming article will describe the characteristics of the repository architecture used to store and disseminate DIDs. In that architecture, the OAI-PMH, the OpenURL and concepts from the MPEG-21 Digital Item Processing specification play a fundamental role.

Acknowledgements

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Notes

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Appendix A: LANL DID representing a technical report and metadata describing it

```
<?xml version="1.0" encoding="UTF-8"?>
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
    <didl:Container> {1}
        <!-- DID-identifier -->
```

```
<didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
        <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
            urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b</dii:Identifier>
    </didl:Statement>
</didl:Descriptor>
<!-- PlaceHolder of Container -->
<didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
        <diph:PlaceHolder
            xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
            urn:foo:TechReport</diph:PlaceHolder>
    </didl:Statement>
</didl:Descriptor>
<!-- Creation-datetime of Container -->
<didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
        <didt:Created
            xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
            2003-09-05T21:51:01Z</didt:Created>
    </didl:Statement>
</didl:Descriptor>
<!-- Item accommodating descriptive metadata about technical report -->
<didl:Item> {2}
    <!-- Content-identifier of descriptive metadata -->
    <didl:Descriptor> {5}
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                urn:bar:56-8730</dii:Identifier>
        </didl:Statement>
    </didl:Descriptor>
    <!-- PlaceHolder of Item -->
    <didl:Descriptor> {5}
        <!-- PlaceHolder of Item -->
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <diph:PlaceHolder
                xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                urn:foo:Metadata</diph:PlaceHolder>
        </didl:Statement>
    </didl:Descriptor>
    <!-- Creation-datetime of Item -->
    <didl:Descriptor> {5}
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <didt:Created
                xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                2003-09-05T18:30:07Z</didt:Created>
        </didl:Statement>
    </didl:Descriptor>
    <!-- Relationships on an Item level -->
    <didl:Descriptor>
        <didl:Statement mimeType="text/xml; charset=UTF-8">
            <dir:Relations
                xmlns:dir="http://library.lanl.gov/2003-11/MPEG-21/DIR">
                <rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
                xml:base="urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b">
                <rdf:Description rdf:about="#//didl:Item[1]">
                    <a:isPartOf xmlns:a="http://purl.org/dc/terms/#">
                        <rdf:Description
                        rdf:about="info:sid/library.lanl.gov:lanl-opac">
                            <b:hasType xmlns:b="http://…/Relations#"
                            rdf:resource="http://…/Relations#Collection"/>
                        </rdf:Description>
```

```
                            </a:isPartOf>
                        <rdf:Description>
                        <rdf:Description rdf:about="#//didl:Item[1]">
                            <b:isDescriptiveMetadataOf xmlns:b="http://…/Relations#"
                            rdf:resource="#//didl:Item[2]"/>
                        </rdf:Description>
                        </rdf:RDF>
                    <dir:Relations>
                </didl:Statement>
            </didl:Descriptor>
            <didl:Component> {3}
                <!-- PlaceHolder of datastream -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <diph:PlaceHolder

xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                            urn:foo:Metadata:MARC/XML</diph:PlaceHolder>
                    </didl:Statement>
                </didl:Descriptor>
                <!-Creation-datetime of datastream -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <didt:Created

xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                            2002-05-03T14:30:03Z</didt:Created>
                    </didl:Statement>
                </didl:Descriptor>
                <didl:Resource mimeType="text/xml; charset=UTF-8"> {4}
                        <record xmlns="http://www.loc.gov/MARC21/slim">
                        <leader>01142cam 2200301 a 4500</leader>
                            <controlfield tag="005">19930521155141.9</controlfield>
                            <datafield tag="010" ind1=" " ind2=" ">
                                <subfield code="a">92005291</subfield>
                        </datafield>
                        …
                </didl:Resource>
            </didl:Component>
            <didl:Component> {3}
                <!-- PlaceHolder of datastream -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <diph:PlaceHolder

xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                            urn:foo:Metadata:MARC/RAW</diph:PlaceHolder>
                    </didl:Statement>
                </didl:Descriptor>
                <!-- Creation-datetime of datastream -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <didt:Created

xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                            2001-02-12T11:34:02Z</didt:Created>
                    </didl:Statement>
                </didl:Descriptor>
                <didl:Resource encoding="base64" mimeType="application/marc"> {4}
```

j0iMS4wIiBlbmNvZGluZz0iVVRGLTgiPz4NCjxjb2xsZWN0aW9uIHhtbG5zSJodH

RwOi8vd3d3LmxvYy5nb3YvTUFSQzIxL3NsaW0iPg0KICA8cmVjb3JkPg0KICAgID

```xml
                            PD94bWwgdmVyc2lvb…
                        </didl:Resource>
                    </didl:Component>
            </didl:Item>
            <!-- Item accommodating technical report -->
            <didl:Item> {2}
                <!-- Content-identifier of technical report -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
                            urn:bar:99-6537</dii:Identifier>
                    </didl:Statement>
                </didl:Descriptor>
                <!-- PlaceHolder of Item -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <diph:PlaceHolder
                            xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                            urn:foo:FullReport</diph:PlaceHolder>
                    </didl:Statement>
                </didl:Descriptor>
                <!-Creation-datetime of Item -->
                <didl:Descriptor> {5}
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <didt:Created
                            xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                            2003-09-05T18:30:07Z</didt:Created>
                    </didl:Statement>
                </didl:Descriptor>
                <!-- Relationships of Item -->
                <didl:Descriptor>
                    <didl:Statement mimeType="text/xml; charset=UTF-8">
                        <dir:Relations
                            xmlns:dir="http://library.lanl.gov/2003-11/MPEG-21/DIR">
                            <rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
                            xml:base="urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b">
                            <rdf:Description rdf:about="#//didl:Item[2]">
                                <a:isPartOf xmlns:a="http://purl.org/dc/terms/#">
                                    <rdf:Description
                                    rdf:about="info:sid/library.lanl.gov:lanl-tr">
                                        <b:hasType xmlns:b="http://…/Relations#"
                                        rdf:resource="http://…/Relations#Collection"/>
                                    </rdf:Description>
                                </a:isPartOf>
                            <rdf:Description>
                            <rdf:Description rdf:about="//didl:Item[2]">
                                <b:hasDescriptiveMetadata xmlns:b="http://…/Relations#"
                                rdf:resource="#//didl:Item[1]"/>
                            </rdf:Description>
                            </rdf:RDF>
                        <dir:Relations>
                    </didl:Statement>
                </didl:Descriptor>
                <didl:Component> {3}
                    <!-- PlaceHolder of datastream -->
                    <didl:Descriptor>
                        <didl:Statement mimeType="text/xml; charset=UTF-8">
                            <diph:PlaceHolder

    xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                                urn:foo:FullReport/PDF</diph:PlaceHolder>
                        </didl:Statement>
```

```
            </didl:Descriptor>
            <!-Creation-datetime of datastream -->
            <didl:Descriptor> {5}
                <didl:Statement mimeType="text/xml; charset=UTF-8">
                    <didt:Created

xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                        2000-03-11T18:22:33Z</didt:Created>
                </didl:Statement>
            </didl:Descriptor> {5}
            <didl:Resource encoding="base64" mimeType="application/pdf"> {4}
                PSJjIj5jMTk5My48L3N1YmZpZWxkPg0KICAgIDw9uIHhtbG5zSJodHgKICAgIDxk
                dGFnPSIzMDAiIGluZDE9IiAiIGluZDI9IiAiPg0KICAgICAgPHN1YmZpZWxkIGNv
                cmVzdG9yZWQgdG8g…
            </didl:Resource> {4}
            <didl:Resource mimeType="application/pdf"
                ref="http://foo/bar/733902fg992.pdf"/>
        </didl:Component>
    </didl:Item>
  </didl:Container>
</didl:DIDL>
```