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Abstract

The vision of MPEG-21-the multimedia framework-is to enable transparent and augmented use of multimedia resources across a wide range of networks and devices used by different communities. As the initial standardization effort for MPEG-21 reaches its conclusion, this article explores one case scenario and examines whether MPEG-21 can achieve its vision.

Keywords

digital item, digital item use case, MPEG-21, multimedia framework, multimedia journalism, transparent and augmented multimedia

Disciplines

Physical Sciences and Mathematics

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MPEG-21 in a Backpack Journalism Scenario

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The vision of MPEG-21—the multimedia framework—is to enable transparent and augmented use of multimedia resources across a wide range of networks and devices used by different communities. As the initial standardization effort for MPEG-21 reaches its conclusion, this article explores one case scenario and examines whether MPEG-21 can achieve its vision.

MPEG-21 is a framework that enables the integration of technologies to support multimedia delivery. We'd like to highlight MPEG-21's potential usefulness by showing how to apply its capabilities throughout an entire delivery chain (relevant to the use case scenario in this article). We depict this process in Figure 1.

Our scenario will show how MPEG-21 fulfills its vision of "transparent and augmented use of multimedia resources across a wide range of networks and devices used by different communities."¹ During the walkthrough of our scenario, we'll see the creation, modification, and use of a Digital Item (DI) as it progresses along the delivery chain with interactions by various Users. We'll also have the opportunity to see some functionalities enabled by MPEG-21 and explore the benefits of using the standard.

Basics of MPEG-21

Before we walk through our use case scenario, we should review the basic concepts of MPEG-21. Two key concepts in the MPEG-21 multimedia framework are

- the DI (the what) and
- the User (the who).

A DI can be thought of as a structured digital grouping of media resources and metadata. It can

include resources of any media type—for example, audio and video clips, text, images, PDF files, spreadsheets, and so on.

Metadata can be information related to the DI as a whole, or parts of the DI (including the resources). The structure of a DI is declared by a Digital Item Declaration (DID).

Part 2 of MPEG-21² specifies a conceptual DID model for declaring DIs and an Extensible Markup Language (XML)-based language—the Digital Item Declaration Language (DIDL) for representing DIDs in XML. DIDL provides a standard representation for declaring DIs.

Other parts of MPEG-21 (see <http://mpeg.chiariglione.org>) enable, for example, a standard way for identifying DIs and their parts; the expression, management, and protection of rights associated with DIs and their parts; and the adaptation of DIs and their resources. We'll discuss these and other parts of MPEG-21 later in this article. (To see some of the terminology we'll be using, see the "Abbreviations" sidebar.)

A User is any entity who interacts in the MPEG-21 environment or uses DIs. This includes individuals, consumers, communities, organizations, corporations, consortia, governments, and so on. Note that in MPEG-21, the term user with an uppercase "U" is used to denote this MPEG-21 definition of a User. A User can interact in the MPEG-21 environment and use DIs in many ways—such as creating, aggregating, publishing, delivering, consuming, or reviewing. Increasingly, Users act in a number of these roles and at various points in the process. These interactions can take place in a wide variety of environments, with varying network conditions, using terminals with a broad range of capabilities.

In basic terms, MPEG-21 can be thought of as a framework in which interactions between Users take place using DIs. You can find a more detailed discussion of the goals and achievements of MPEG-21 (at the time of its writing) in a previous issue of *IEEE MultiMedia*.³ That article also provides information on MPEG-21 in the context of previous MPEG standards and the motivation for developing MPEG-21. You can also find further technical overviews of some parts of MPEG-21 in the special section on MPEG-21 in the June 2005 issue of *IEEE Transactions on Multimedia*.⁴ We also provide further information on MPEG-21 in the sidebars "MPEG-21: Freely Available Parts" and "The DID Second Edition" (see p. 26).

A story to tell

Now that we've covered some background and MPEG-21 basics, let's start our use case scenario by meeting Adele. Adele is a freelance multimedia journalist, also known as a *backpack journalist* (you can find some interesting reading on backpack journalism elsewhere^{5,6}). As Adele's job title suggests, she's capable of gathering and reporting information in a variety of media. Her tools out in the field include a digital voice recorder, digital camera, digital camcorder, portable scanner, PDA, mobile phone, and notebook computer.

Adele is putting together a human interest story on what is currently a small town. In the past—60 years ago—it was a thriving mining town. But the mine closed and the population dwindled as people left to find work elsewhere. Adele wants to tell the story of the town's transformation and what the future holds for the residents. She will do this by including video interviews, images, text, voiceovers, background music, and so on.

Create

As a first step, before Adele leaves home, she fires up her DI editing software and creates a working DI to act as a container for all the media she'll produce and collect. This container can also be a place to store the final DI that will be published and consumed. So Adele actually creates a container that itself contains another container (for her collected items), and then the DI (we'll call this the story DI) she'll use as the published story.

DIDL documents and their top-level elements. As Figure 2 shows, at the top level a DIDL document has a DIDL element. This may have either a single Container child element or single Item child element. Technically, a Container isn't itself a DI but allows grouping of other Container elements and/or Item elements. In Adele's case, her top-level Container will contain a child Container for collected media, and then a child Item that will eventually represent the final story DI.

As part of the initial creation of the working DI, Adele has set the preferences of her DI editing software to automatically generate a descriptor for her container that captures creation information, including the creator (Adele), the creation date, and the software used to create the working DI. By clicking the appropriate button,

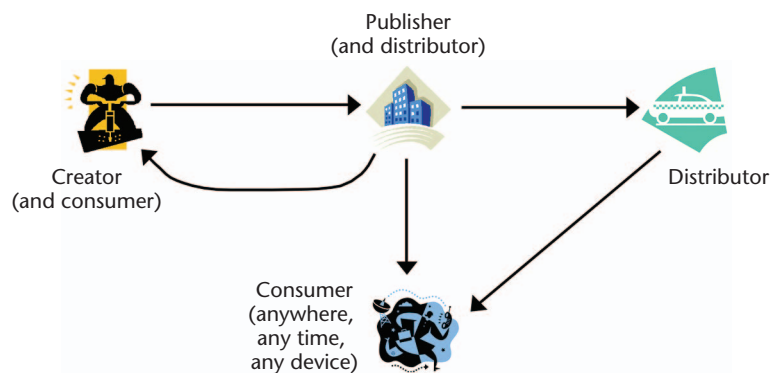


Figure 1. Using MPEG-21 throughout the multimedia delivery chain.

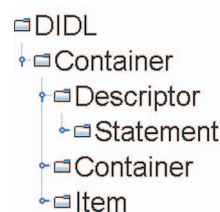


Figure 2. Initial working DID.

Abbreviations

As with all good standards, MPEG-21 uses numerous abbreviated terms. The part of MPEG-21 with which an abbreviation is primarily associated is also indicated.

DI	Digital Item
DIA	Digital Item Adaptation (part 7)
DID	Digital Item Declaration (part 2)
DIDL	Digital Item Declaration Language (part 2)
DII	Digital Item Identification (part 3)
DIP	Digital Item Processing (part 10)
ER	Event Reporting, Event Report (part 15)
ERR	Event Report Request (part 15)
IPMP	Intellectual Property Management and Protection (part 4)
PAT	Persistent Association Technologies (part 11)
RDD	Rights Data Dictionary (part 6)
REL	Rights Expression Language (part 5)

MPEG-21: Freely Available Parts

Part 1 of MPEG-21 is a technical report on the MPEG-21 vision, technology, and strategy and contains an overview and basic concepts of the other parts (at the time of its publication) of MPEG-21. This technical report is publicly available from the ISO/IEC Information Technology Task Force (ITTF). Visit <http://www.iso.ch/ittf>, click the "Freely Available Standards" link, and look for ISO/IEC TR 21000-1. The MPEG-21 XML Schema files are also publicly available at the same location.

The DID Second Edition

Part 2 of the MPEG-21 Digital Item Declaration (DID) was first published in 2003. In 2005, MPEG finalized a second revised edition. Here we briefly describe some of the main differences between the first and second edition of DID.

Resource element

A resource in a DI is represented by a Digital Item Declaration Language (DIDL) Resource element. A number of revisions have been made to the Resource element. First, an encoding attribute has been added that we can use if the resource is included by value (its data is embedded in the content of the Resource element) as base64-encoded data. In addition, a contentEncoding attribute has been added to allow the encodings that have been applied to the resource to be specified (independent of whether it's included by value). This acts as a modifier to the value of the mimeType attribute. For example, if the resource is an MP3 audio file that has been Gnu zip (GZIP) compressed, the mimeType would be audio/mpeg and the contentEncoding would be gzip.

Another revision to the Resource element is that it can now contain well-formed XML as its content (that is, it can represent an XML-based resource included by value). Finally, the localPath attribute has been removed. We can implement this functionality using an attribute descriptor.

Goodbye Reference, hello XInclude

In the DID first edition, the Reference element allowed the

content of some elements to be included into the contents of another (like-named) element. This type of functionality is now enabled by the World Wide Web Consortium's (W3C's) recommendation on XML Inclusions (XInclude), published in December 2004. Hence, in the DID second edition, the Reference element has been removed and the use of XInclude is allowed.

Attribute descriptors

A descriptor associates information with another entity in the DI and is represented by a DIDL Descriptor element. The DID second edition adds the ability to represent a descriptor as an attribute on a DIDL element. This is achieved by allowing any attributes from other namespaces on DIDL elements that may have Descriptor child elements.

Fragment identification

An anchor binds descriptors to a fragment of a resource and is represented by a DIDL Anchor element. In the DID first edition, the fragment is identified by a Uniform Resource Identifier fragment identifier value of a fragment attribute of Anchor. The DID second edition adds the ability to identify the fragment by XML-based metadata (such as MPEG-7 media locators). It achieves this by removing the fragment attribute of Anchor and adding a child Fragment element.

```
<Descriptor>
  <Statement mimeType="text/xml">
    <Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
      <DescriptionUnit
        xsi:type="CreationInformationType">
        ...
      </DescriptionUnit>
    </Mpeg7>
  </Statement>
</Descriptor>
```

Figure 3. Descriptor containing MPEG-7 metadata.

Adele already has some research and writes some short introductory text, authored as HTML in her favorite HTML editor. She creates a subitem of the story DI and drops in her introductory text as a component of this subitem. (According to the preferences of Adele's DI editing tool, a descriptor containing the creation date of the created entity is added to every item and component that's created.) She also gives this subitem (let's call it the introductory item) a title. Later she'll add some wide-shot images of the town captured using her digital camera.

Adele can enter a working title and some initial text for an abstract.

Metadata is contained in a Descriptor element. The automatically generated descriptor for the container is represented by a Descriptor element (see Figure 3), which is added as a child of the top-level Container. Adele's preferences are set so that the creation information is captured as MPEG-7 metadata.⁷

Structuring the DI. The first bit of structure added to the story DI (see Figure 4) is a child Item element (a subitem) to the Item representing the story DI. The content of this Item currently includes one component, represented by a Component child element. Adele's HTML text is represented by a Resource child element of the Component. A Descriptor child element is also automatically created for both the new subitem and Component capturing their creation date and time using MPEG-7 metadata.

On the road

On the outskirts of the town, Adele stops to take some photos, and then continues into the town. She stays for a week, visiting the local library, mayor, local historian, and several other people spanning different generations. All the while, Adele is taking photos, shooting videos of interviews and town life, and recording voice notes.

At the end of each day Adele transfers all her media to her laptop. Using her DI editing software, she also imports each resource as an item into her collected items container. At the moment, the container is just a grouping of all Adele's collected items.

Component and Resource elements. Each collected item is represented by an Item element (as a child of the collected items within the Container element—see Figure 5), containing Descriptor child elements and a Component child element. The Component in turn contains Descriptor child elements and a Resource element, which represents the imported resource.

The actual media resource isn't physically included within the Resource element, but instead is referred to via a Uniform Resource Identifier (URI) given as the value of the ref attribute of the Resource element (the media type information is captured by a mimeType attribute on the Resource element).

In MPEG-21, you don't need to embed the media resources themselves in the DI. However, if a given application requires it, MPEG-21 also allows the media resource data to be embedded in the DI. In Adele's case, she uses JPEG for her still images, MPEG-4 for her video, and MPEG-1/2 Layer III (MP3) for her audio recordings.

Each item gets a descriptor with the creation date of the item and contains a single component with the imported resource. The DI editing software can also add automatically generated descriptors. For example, it can translate Exchangeable Image File Format (EXIF) information from Adele's digital camera images (saved in JPEG format) to MPEG-7 metadata, thereby enabling searches based on MPEG-7 metadata.

Resource metadata. Note that the metadata is stored in Descriptor elements external to the resource media data, but bound to the Resource element representing the resource by the parent Component element. This enables access to the metadata (for example, for searching) without

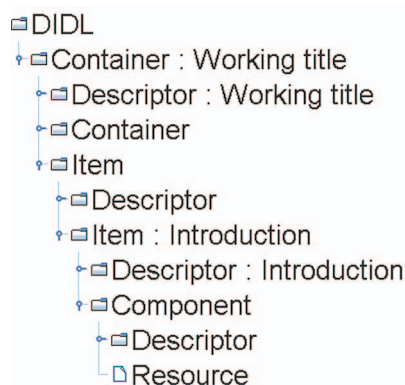


Figure 4. Introducing the Introduction subitem.

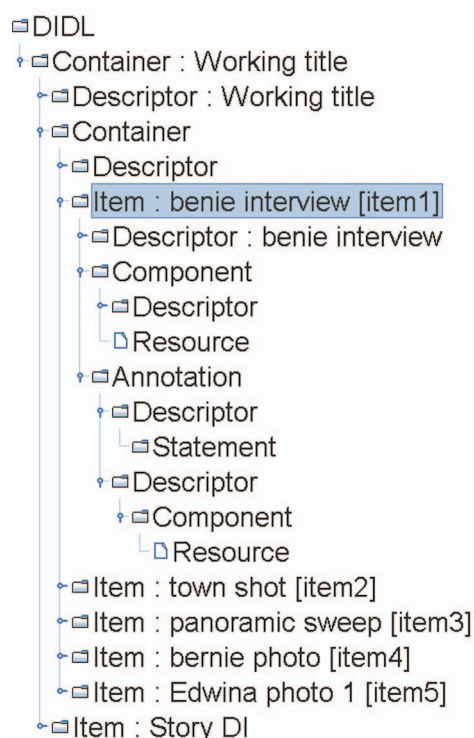


Figure 5. Filling up the collected items container.

having to examine the actual resource media data itself. So far we've described Descriptor elements containing MPEG-7 metadata. Such textual metadata is represented by a Statement child element of a Descriptor element. However, a Descriptor can also contain a Component, which could contain a Resource representing, for example, a thumbnail image of a full-size image.

Adele also adds text and voice recordings (in MP3 format) to remind her about the context of each collected item. Since this information is primarily for Adele's benefit and won't be included in the story DI, Adele adds them as annotations to the collected item.

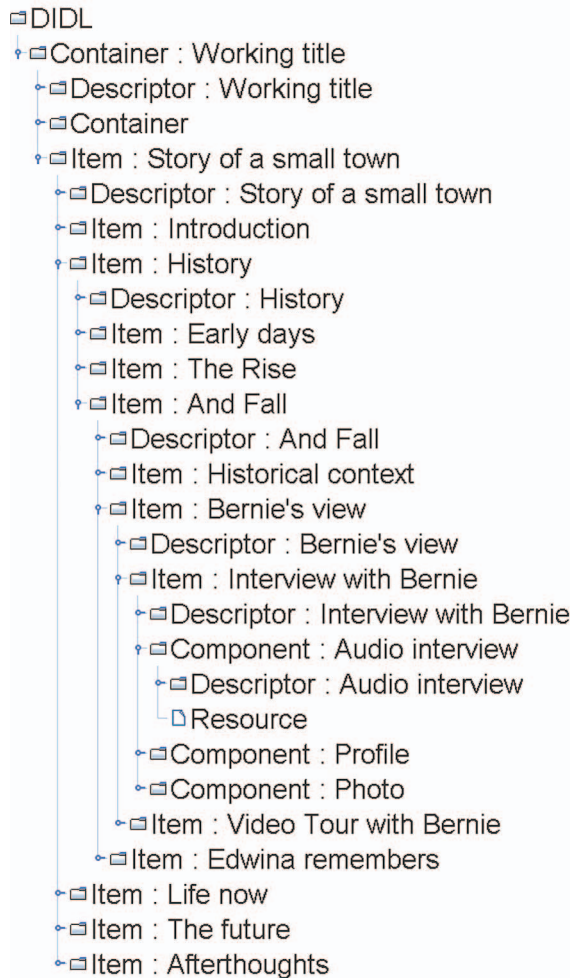


Figure 6. Story DI structure.

Annotations. Annotations are represented via an Annotation element (see Figure 5). In this case the Annotation elements associate additional descriptors to a collected item, but we don't consider those descriptors an intrinsic part of the item.

Adele can then use her DI editing software to sort the items in her collected items container, based on creation date and media type. As she develops the story DI, she can copy items or components from items into subitems of the story DI.

Putting it together

Back home, Adele finishes putting together the story DI. In addition to the introductory subitem of the story DI, she decides to structure the collected information by adding subitems to the story DI for the town history, life in the town now, and the town's future. Each of these items will in turn be structured with further subitems—for example, the history item is structured with a

subitem for the early history, the history of the town at its height, and the history of the mine's decline. See Figure 6 for a depiction of the story DI's final structure.

Adele can use her DI editor in expert mode, where the DI author sees the internal structure of the DI, as Figure 6 shows. Or she can use easy mode, which provides visual representations of the items and components and lets Adele put her story DI together by manipulating the visual representations of the DI elements.

In addition, the DI editing software includes a DI presentation editor. This lets Adele specify the visual presentation of each item in the DI. The tool automatically adds appropriate descriptors containing the information required to present the items according to Adele's wishes.

Presentation. MPEG-21 maintains a separation of data and presentation, and in fact doesn't specify any specific mechanisms for presenting a DI. However, Adele's DI editing software lets her use a presentation method that transforms the DIDL to HTML. The transformations are specified using the World Wide Web Consortium (W3C) Extensible Stylesheet Language (XSL) family of recommendations. The XSL Transformation (XSLT) rules are included as part of the metadata for each Item (in a Descriptor child element of each Item).

Adele's DI editing software also incorporates a DI browser so that she can periodically check how the story DI will be presented.

Publish

Now that Adele has her story DI as she wants it, she contacts Good Yarns multimedia publishers (we'll use GY for short). GY publishes multimedia titles in a number of formats, including the Internet and on CD- and DVD-ROM. Adele has had work published with GY before.

Adele videoconferences with her GY contact, Henrik, and shows him her latest work. They agree on the usual terms, and Henrik generates a unique identifier for Adele's latest DI and provides this to her.

At the moment, Adele's working DI includes the container of her collected items and the story DI. Additionally, all the resources in the working DI (and story DI) are referenced (via URIs) to local copies of the media files on Adele's laptop.

Adele uses the "prepare for publisher" functionality of her DI editing software. This extracts the story DI from Adele's working DI, organizes

the media files, and fixes the URI references in the extracted story DI. As part of the process Adele also identifies her story DI using the unique identifier provided to her by Henrik.

Identifiers. The unique identifier for Adele's story DI is included as a Descriptor child element of the top-level Item element of the story DI. The actual value of the identifier is carried in an Identifier element as specified by part 3 of MPEG-21, Digital Item Identification (DII). Since it's an XML value that's textual, the DII Identifier is contained in a Statement child element of the Descriptor.

In addition, Adele creates a digital license that expresses the standard rights she normally grants to GY in publishing her work. GY is granted rights to distribute Adele's story DI, and also to create derived DIs whose content and structure is substantially the same, but may be adapted, as well as extract DIs whose content and structure is substantially the same as a part of the original DI (and may be adapted).

Rights. The rights in the digital license are expressed using the Rights Expression Language (REL) specified by part 5 of MPEG-21.⁸ We can use the REL to express rights for actions, such as Modify, as defined by part 6 of MPEG-21,⁹ the Rights Data Dictionary (RDD).

Adele burns the DID representing the extracted story DI, the resources, and the license onto a DVD as a backup, then zaps a disk image of the DVD to Henrik using a broadband network link.

Getting it ready

When Henrik receives Adele's DVD image, he passes it on to Ines to prepare for publication, in consultation with Adele. Ines stores Adele's original story DI and creates a new DI, almost identical to Adele's original.

The first difference is that this DI (let's call it the publishing DI) has its own unique identifier. However, the semantic link to Adele's original DI is maintained by including the identifier of Adele's original story DI as a related identifier of the publishing DI.

Identifiers and related material. An identifier that doesn't identify the DI (or a part of it) itself, but identifies something related, is carried in a Descriptor-Statement containing a DII RelatedIdentifier element.

Another difference is that each of the media

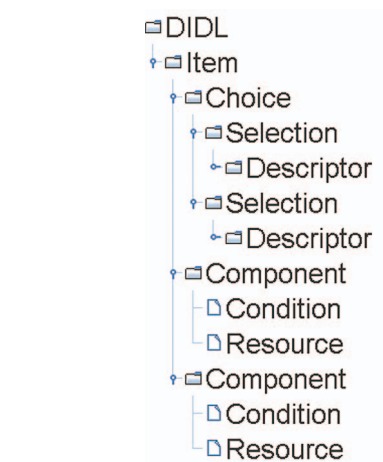


Figure 7. Conditional components based on predicate states embodied by selections in a choice.

resources is stored in a multimedia database and the URI references to the media in the publishing DI are updated accordingly.

In addition, Ines creates a set of duplicate, low-resolution resources, for all video, image, and audio media in the DI. She then uses GY's DI editing software to incorporate these low-resolution resources into the publishing DI. This process basically involves duplicating the component containing the original resource, but replacing the resource in the duplicate component with the low-resolution resource. Then it's a matter of making each component available only under certain specified (mutually exclusive) conditions.

Condition, Choice, and Selection elements.

To make an element in a DIDL document conditional, we use a Condition element, as Figure 7 depicts. However, the Condition element doesn't operate in isolation. A Condition element specifies the state that one or more predicates must be in for the Condition to be satisfied. These predicates are embodied by Selection elements that are in turn contained as child elements of a Choice element. In this case, the conditional Component elements will contain child Condition elements, and associated Choice elements will be contained as children of the top-level Item element of the publishing DI. In this case, the predicate information is based on the User Environment Description (UED) tools as specified by part 7 of MPEG-21, Digital Item Adaptation¹⁰ (DIA).

Ines also adds Event Report Requests (ERRs) so that Event Reports (ERs) will be sent to GY when certain actions take place on the DI. For example, an ERR might request an ER when a consumer plays an item containing an interview. Such

Event Reports could be used to calculate royalties, for example.

Events. The XML-based expression of ERRs and ERs is specified by part 15 of MPEG-21, Event Reporting. The Event Reporting also uses RDD-defined terms to indicate what actions to report.

The final step for Ines is to protect the contents of the DI. For this case, only a simple protection policy is applied. She protects the introduction item separately from the rest of the DI. This allows any registered User who has agreed to a general license agreement to view the introduction item. She can make the rest of the DI available separately—for example, for registered Users who have subscribed to a higher-level service.

Protection. Part 4 of MPEG-21, Intellectual Property Management and Protection Components (IPMP Components), provides the technical tools enabling protection of a DI and its parts. It doesn't specify any actual DRM system, but provides the hooks for these to be incorporated in a DI. IPMP can protect any element in a DID, and supports protection at the resource level.

Distribute and consume

The publishing DI is now ready for distribution. As an indication of the diversity of roles enabled by today's technologies, the DI will be distributed via Adele's own Web site, via a Web site run by GY, and via a third online media distribution company, the Go21 Online Store (a spin-off from a major traditional media company). In some cases, such as for the Go21 Online Store, GY might further package the DI along with a digital license expressing the distribution rights.

Now that we've seen how it's distributed, let's consider who might access the story and how they'd go about it.

Accessing MPEG-21 DIs in the office

Jon is a researcher for a government agency and is investigating the social impact of past changes in government policy. A friend who is a regular at Go21 told Jon about Adele's story. Jon finds his way to the Go21 Web site, does a search, and finds Adele's story listed in the search results. The search engine at Go21 uses the metadata in the DI descriptors.

Jon's agency is a Go21 subscriber, so when he chooses the DI and authenticates his identity, he can download the DI to his desktop computer. When he views the DI using his DI browser, the

IPMP information informs his browser what to do to enable access to the content of the DI. In this case, it includes obtaining license details from the GY license server and sending an ER (which could trigger various transactions among the Users).

The conditions included in the DI by Ines in relation to the choice of resources, combined with Jon's terminal capabilities and preferences, combine to ensure Jon consumes the high resolution resources as he browses the DI (that is, Adele's original resources, as opposed to the low-resolution adaptations created by Ines).

The terminal capabilities and User preferences can also be stored in MPEG-21 DIs containing appropriate resources and metadata, such as Usage Environment Descriptions (UEDs) from MPEG-21 DIA and User preferences descriptions from MPEG-7.

On the go

Kirsten is a keen amateur historian. She's a registered customer with GY, and on her way to work in a wireless-enabled bullet train she's consuming extracts of Adele's DI on her Multimedia Entertainment Center for People On the Go (MECPOG). Kirsten can select any item in the DI to consume on her MECPOG. The item is delivered in an extracted DI that the GY server created dynamically. Based on Kirsten's device capabilities (forwarded to the GY server as part of the request procedure) the extracted DI is also adapted so that it only contains low-resolution resources. The GY license server is first consulted to ensure Kirsten's access is valid according to the terms of her license for this DI. Because Kirsten can choose any item in the DI, the extracted DI might still contain subitems. The extracted DI can be navigated just like any DI.

You must listen to this

Adele is lunching with a friend and decides that her friend should listen to the interview Adele recorded with Edwina, a resident of the small town. All Adele has available at the moment is her mobile phone. She uses an application on her mobile phone to formulate a request for the item in her DI that contains Edwina's interview and sends the request to a service operated by GY.

The capabilities of Adele's device are stored on a GY server. Based on Adele's request and device capabilities, the server creates an extracted DI containing only the item's audio component.

Adele hands her mobile phone to her friend who listens to the interview with Edwina.

Conclusions

MPEG-21 is an ambitious undertaking and we've only partly explored the breadth of the multimedia framework in this article (see the sidebar "MPEG-21 Moving Forward"). With the completion of the second edition of the DID part, some maturity now exists in the concepts and use of DIs as the "what" (the core versatile container of the framework). The key to the framework's adoption will be the targeting of market applications. The walkthrough in this article demonstrates how we can apply the DI to one of many complete delivery chain scenarios.

In our scenario, we showed how MPEG-21, the multimedia framework, enables a structured digital grouping of resources along with metadata to be defined and declared as an MPEG-21 DI. We saw how we can use other MPEG standards in the context of MPEG-21 (as media resources and metadata).

However, as a framework, MPEG-21 itself is agnostic as to the media type of resources and the metadata. By using relevant resources and metadata to a particular market application, MPEG-21 could be used in a diverse range of applications.

For example, applications of MPEG-21 could be as diverse as a simple (or complex) digital collection of photos, learning objects, electronic patient files, or digital magazines and newspapers. Within a given application, interoperability will depend to some extent on agreed upon structures, resources, metadata, and so on within that application. However, as diverse as the applications might be, MPEG-21 provides interoperability such that all these applications can use a single standardized framework.

As the final parts of the framework are put in place, the advantages of a complete, standardized framework for multimedia are becoming clearer. The ultimate test will, of course, come as Users determine whether MPEG-21 has indeed provided them with "transparent and augmented use of multimedia resources across a wide range of networks and devices used by different communities."¹

MM

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MPEG-21 Moving Forward

Several significant parts of the MPEG-21 jigsaw puzzle are now in place and the tools described in this article are beginning to appear as products. However, to achieve the goal of universal access to content, we need several extras to complete the MPEG-21 vision.

DI Streaming

Digital Items (DIs) are collections of content and are declared statically using the XML Digital Item Declaration. However, many Users won't want to interact with the DIs as a collection of on-demand downloadable pieces of content. Rather, the content will need to be pushed to Users over time as a stream and integrated into a time-based presentation. Thus, Digital Item Streaming is a new area of work at MPEG that binds the content of a DI to a transport stream, letting the DI be fragmented into a stream of access units. The aim of the work is to provide a versatile, standardized, and universal way to stream complex multimedia content that may include video, audio, documents, applications, and metadata. Once these streams are generated from the static DIs, we expect that a range of applications will be enabled. In particular, standardized metadata enabling adaptation of the streaming content using Digital Item Adaptation (DIA) tools could be possible.

Multimedia Application Formats

MPEG-A, for Multimedia Application Formats¹ (MAFs), is being developed as a new way to look at the MPEG standards. (See also the "MPEG-A" article in this issue of *IEEE MultiMedia*, by K. Diepold, F. Pereira, and W. Chang.) The MAFs are specifically targeted at particular application spaces and are standards built up from relevant parts of the existing MPEG collection. This new approach is important for MPEG-21, as the breadth of MPEG-21 and its parts makes adoption of the entire standard by any market unlikely.

Instead, markets and consortia are expected to choose a targeted subset of the MPEG-21 parts that meet their requirements. The intention of the MAFs is to make that job easier in spaces where MPEG has clear expertise. At the time we wrote this article, the first MAF—MPEG-A Part 2, the MPEG music player application format—was complete and shows Users how MPEG-21, MP3s, and MPEG-7 can be combined to create a rich music format capable of carrying metadata-enhanced music tracks and albums.

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