Sharing e-Learning Object Metadata Using ebXML Registries for Semantic Grid Computing

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Abstract

To facilitate the processes of e-learning resource description, discovery and reuse, e-learning objects should be appropriately described and classified using standard metadata that need to be published in a registry to reduce duplication of effort and enhance semantic interoperability. This paper describes how standard ebXML registries can be used for semantic grid computing for annotating, storing, discovering and retrieving e-learning object metadata. For semantic annotation of e-learning objects, IEEE Learning Object Metadata (LOM) is adopted as the metadata ontology. In order to support the e-learning metadata ontology in interoperable ebXML registries, a mapping scheme between LOM and ebXML Registry Information Model (RIM) is proposed. The usefulness of sharing e-learning object metadata is demonstrated by prototyping a semantic registry based on the scheme.

Keywords: Metadata, e-Learning, LOM, e-Business, ebXML, semantic grid

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1. Introduction

Learning objects can be reused only if they are easily located, evaluated, adapted, and adopted by educational practitioners. In order to facilitate this process of resource description, discovery and evaluation, learning objects should be appropriately described, classified and indexed using standard metadata. Metadata are data that describe a physical or electronic resource and can be used to manage collections of documents, images, and other information in a repository such as an archive or library. Metadata are helpful because they provide standard buckets for keeping data about almost any e-learning resources. The most broadly accepted meta-data standard in e-learning is IEEE Learning Object Metadata (LOM) [2]. With a structuralist approach, it provides 60 elements as a means of developing more comprehensive descriptions of learning objects and of providing support for user services. The metadata standard is also included in key IMS and ADL specifications such as Learning Resource Meta-data (LRM) [3] and Shareable Content Object Reference Model (SCORM) [4].

The LOM standard defines controlled vocabularies for certain elements. However, for undefined elements users must choose their own vocabularies. The choice of an appropriate vocabulary for each element is crucial in facilitating successful search and retrieval of learning objects and in ensuring that metadata records are interoperable. For these undefined elements, implementers must choose vocabularies that are appropriate and meaningful to their community of users. Even where the standard defines a controlled vocabulary for an element, implementers must ensure that they interpret and use the controlled vocabulary appropriately and consistently. Without semantic interoperability (i.e. consistent use of domain concepts - metadata elements and controlled vocabularies) [5], users cannot cross search repositories of learning objects and evaluate the potential of resources to fulfill their requirements. It is recommended that metadata implementers publish their metadata including vocabularies in a registry to reduce duplication of effort and facilitate semantic interoperability [6]. For example, a learning resource registry and discovery system [7] has been developed for sharing and reusing e-learning resources. However, this kind of e-learning registry is based on proprietary information models and interfaces, which limit its capability for the management and sharing of the e-learning resources.

This paper employs e-Business eXtensible Markup Language (ebXML) registry standards comprising ebXML Registry Information Model (ebRIM) [8] and ebXML Registry Service (ebRS) [9] in order to boost semantic interoperability. ebXML is designed for electronic interoperability, allowing businesses to find each other, agree to become trading partners and conduct businesses. All of these operations can be performed automatically, minimizing, and in most cases completely eliminating the need for human intervention. ebXML registries provide a set of services that allow interested parties to share information to enable business process integration. The shared information may be persisted as objects in a repository. ebXML registries provide the additional benefits of discovery and maintenance of registered content, support for collaborative development, secure version control of registered content, federation of cooperating registries to provide a single view of registered content by seamless querying, synchronization, and relocation of registered content.

In order to support the storage, discovery, and retrieval of e-learning object metadata using ebXML registries, this paper presents a mapping scheme between LOM and ebXML RIM that allows ebXML registries to act as a large-scale distributed foundation for representing and managing e-learning metadata [1]. As semantic grid computing involves the autonomous discovery and assembly of distributed remote resources, federated ebXML registries offer an infrastructure for the meta information in semantic grid computing [10].

This paper is organized as follows: Section 2 summarizes LOM as the e-learning object metadata ontology and Section 3 introduces the features provided by ebXML RIM for the ontology. Section 4 presents the method for expressing and implementing e-learning object metadata in ebXML registries based on the mapping scheme between LOM and ebXML RIM. Finally, Section 5 concludes the paper with some future research directions.

2. LOM as the e-Learning Object Metadata Ontology

LOM is an internationally recognized IEEE standard (1484.12.1–2002) [2][11] for the description of learning objects. A learning object is any entity, digital or non-digital, that may be used for learning, education or training. It is the first part of a multipart standard, and describes the LOM data model. The model specifies which aspects of a learning object should be described and what vocabularies may be used for these descriptions; it also defines how this data model can be amended by additions or constraints.

LOM comprises a hierarchy of elements as shown in **Fig. 1**. The first level contains nine categories, each of which contains sub-elements. These sub-elements may be simple elements that hold data, or may themselves be aggregate elements that contain further sub-elements. The semantics of an element are determined by its context: they are affected by the parent or container element in the hierarchy and by other elements in the same container. For example the various Description elements (1.4, 5.10, 6.3, 7.2.2, 8.3 and 9.3) derive their context from their parent element. In addition, the Description element (9.3) also takes its context from the value of the element Purpose (9.1) in the same instance of Classification.

The data model specifies that some elements may be repeated either individually or as a group. For example the elements Purpose (9.1) and Description (9.3) can only occur once within each instance of the Classification container element. However the Classification element may be repeated, thus allowing many descriptions for different purposes. The data model also specifies the value space and data type for each of the simple data elements. The value space defines the restrictions, if any, on the data that can be entered for that element. For many elements the value space allows any string of Unicode characters to be entered, for other elements entries must be drawn from a declared list (i.e., a controlled vocabulary) or must be in a specified format (e.g. date and language codes).

Other parts of the standard define the bindings of the LOM data model, i.e., they define how LOM records should be represented in XML and RDF (IEEE 1484.12.3 and IEEE 1484.12.4 respectively). As a simple example of the XML binding, **Fig. 2** shows a snippet of an XML LOM specification example. It omits all other categories except general, life cycle, relation and classification.

When implementing LOM as a data or service provider, it is not necessary to support all the elements in the data model, and the LOM data model does not limit the information that may be provided. The creation of an application profile allows a community of users to specify which elements and vocabularies they will use. Elements from LOM may be dropped and elements from other metadata schemas may be brought in; likewise, the vocabularies in LOM may be supplemented with values appropriate to that community. A range of vocabularies is required to fully describe learning objects using the IEEE LOM standard. Each type of specialized or technical vocabulary has its own specific purpose and should be used with specific elements and in specific contexts. The basic principal function of a controlled vocabulary is to act as a tool for describing and organizing discrete physical elements or intellectual concepts.

1 General 1.1 Identifier 1.1.1 Catalog 1.1.2 Entry 1.2 Title 1.3 Language 1.4 Description 1.5 Keyword 1.6 Coverage 1.7 Structure 1.8 Aggregation Level 2 Life Cycle 2.1 Version 2.2 Status 2.3 Contribute 2.3.1 Role 2.3.2 Entity 2.3.3 Date 3 Meta-Metadata 3.1 Identifier 3.1.1 Catalog 3.1.2 Entry 3.2 Contribute 3.2.1 Role 3.2.2 Entity 3.2.3 Date 3.3 Metadata Schema 3.4 Language 4 Technical 4.1 Format 4.2 Size 4.3 Location 4.4 Requirement 4.4.1 OrComposite 4.4.1.1 Type 4.4.1.2 Name 4.4.1.3 Minimum Version 4.4.1.4 Maximum Version	4.5 Installation Remarks 4.6 Other Platform Requirements 4.7 Duration 5 Educational 5.1 Interactivity Type 5.2 Learning Resource Type 5.3 Interactivity Type 5.4 Semantic Density 5.5 Intended End User Role 5.6 Context 5.7 Typical Age Range 5.8 Difficulty 5.9 Typical Learning Time 5.10 Description 5.11 language 6 Rights 6.1 Cost 6.2 Copyright and Other Restrictions 6.3 Description 7. Relation 7.1 Kind 7.2 Resource 7.2.1 Identifier 7.2.1.1 Catalog 7.2.1.2 Entry 7.2.2 Description 8 Annotation 8.1 Entity 8.2 Date 8.3 Description 9 Classification 9.1 Purpose 9.2 Taxon path 9.2.1 Source 9.2.2 Taxon 9.2.2.1 Id 9.2.2.2 Entry 9.3 Description 9.4 Keyword

Fig. 1. Outline of LOM elements

```xml
<?xml version="1.0"?>
<lom>
 <general>
  <identifier><catalog>URN</catalog><entry>urn:hycu:ceb021</entry></identifier>
  <title><string language="en">Introduction to Data Mining</string></title>
  <language>en</language><language>kr</language>
  <description><string language="en">An introductory course on data mining for non-experts
                    </string>
  </description>
  <keyword><string language="en">data mining</string></keyword>
  <keyword><string language="en">classification</string></keyword>
  <keyword><string language="en">rule induction</string></keyword>
  <structure><source>LOMv1.0</source>
                 <value><string language="en"> atomic</string></value>
  </structure>
 </general>
 <lifeCycle>
  <version><string language="en">1.0</string></version>
  <status><source>LOMv1.0</source><value><string language="en">final</string></value>
  </status>
  <contribute>
   <role><source>LOMv1.0</source><value><string language="en">author</string></value>
   </role>
   <entity>BEGIN:VCARD\nFN:Hyoung Do\nEMAIL;
              TYPE=INTERNET:hdkim@hycu.ac.kr\nEND:VCARD</entity>
   <date><dateTime>2006-01-10</dateTime></date>
  </contribute>
 </lifeCycle>
 … (other categories are omitted)
 <relation>
  <kind><source>LOMv1.0</source><value>isbasedon</value></kind>
  <resource>
   <identifier><catalog>ISBN</catalog><entry>89-601-4001-5</entry></identifier>
   <description><string language="en">Understanding of Data Mining </string></description>
  </resource>
 </relation>
 <classification>
  <purpose><source>LOMv1.0</source>
   <value><string language="en">accessibility</string></value>
  </purpose>
  <taxonpath>
   <source><string language="en">ISO3166</string></source>
   <taxon><id>kr</id><entry><string language="en">Korea, Republic Of</string></entry>
```

Fig. 2. XML LOM specification example

3. ebXML Registry and Semantic Grid Computing

Simply put, grid computing is distributed computing across multiple administrative domains [12]. Semantic grid computing can also be defined as an extension of the current grid computing, in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation. Semantic grid computing involves the autonomous discovery and assembly of distributed resources which are described in standard ways that can be processed by computers [10]. The descriptions constitute metadata, typically represented using semantic web technologies. Semantic grid computing can also be defined as an extension of the current grid computing, in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation. All stakeholders in semantic grid computing need to be able to publish and discover resources that have been exposed as grid services. An ebXML registry is capable of containing such grid meta-information as it allows publishers to retain ownership of their content and knowledge classifications using logically or externally stored taxonomies. Although semantic web ontologies are not supported in the current version, ebXML registries can be used for the sharing and reuse of semantic metadata such as LOM. While grid computing offers a way of distributing system resources dynamically, ebXML can provide open standards for its users to discover and use available resources across the system [13]. ebXML collaboration and choreography standards are expected to make it easy to compose interoperable peer-to-peer collaborations between any types of grid service participants regardless of the supporting platform or programming model used.

An ebXML registry is an information system that securely manages any content type and the standardized metadata that describe it. It provides a set of services that enable sharing of content and metadata between organizational entities in a federated environment. An ebXML registry may be deployed within an application server, a web server or some other service container. The registry may be available to clients as a public, semi-public or private web site. The ebXML registry thus provides a stable store where submitted information is made persistent. Such information is used to facilitate business to business relationships and transactions.

The ebXML registry standard comprises of two specifications: ebRIM [8] and ebRS [9], where the former defines the types of metadata and content that can be stored in an ebXML registry and the latter the services provided by an ebXML registry and the protocols used by clients of the registry to interact with these services.

According to the ebRIM specification, an ebXML registry is capable of storing any type of electronic content such as XML documents, text documents, images, sound and video files. Instances of such content are referred to as a repository item, which is stored in a content repository provided by the ebXML registry. In addition to the repository items, such an ebXML registry is also capable of storing standardized metadata that may be used to further describe those repository items. Instances of such metadata are referred to as a RegistryObject (RO), or one of its sub-types. ROs are stored in the registry provided by the ebXML registry. An RO instance may be associated with other RO instances through Association class, an instance of which may be used to associate any two RO instances. There are a number of predefined association types (e.g. RelatedTo, HasMember, ExternallyLinks, Contains, EquivalentTo, Extends, Implements, InstanceOf, Supersedes, Uses, Replaces, SubmitterOf, ResponsibleFor and OffersService) that a registry must support to be ebXML compliant. Logically-related RO instances can be grouped by a RegistryPackage (RP) instance. Furthermore, an RO may be classified in many ways. In order to support a general ClassificationScheme (CS) that can support single level as well as multi-level classifications, the information model defines Classification, CS, and ClassificationNode (CN) classes and related associations.

In addition to the classification and association information, ebXML RIM supports various aspects of information as follows:

- provenance information model for describing the parties responsible for creating, publishing, or maintaining ROs and/or repository items.

- service information model for the registration of web services as well as other types of services.
- event information for supporting event notification by subscribing a pre-configured AdhocQuery instance as a selector to select some AuditableEvents of interest to the subscriber and one or more Actions to deliver the selected events to the subscriber.
- cooperating registries information for enabling multiple registries to seamlessly provide a unified information store that enables clients to discover any information using a single federated query that searches all members of the federation. Information in one registry can seamlessly link with information in any other registry and any information from one registry may be replicated in any other registry
- access control information used by a registry to control access to ROs and repository items managed by it.

An ebXML registry allows users to define semantics through the following three extension mechanisms.

- First, it allows attributes of ROs to be defined through slots. Slot instances provide a dynamic way to add arbitrary attributes to RO instances.
- Second, it allows additional types of associations between ROs to be defined when necessary. An Association instance represents an association between a source RO and a target RO. If there is a need for additional mechanisms to express multiple inheritance, for example, we can define a “subClassOf” association for this purpose.
- Third, ebXML classification hierarchies allow more complex semantics to be defined and queried both through the slot mechanism and through the predefined associations between RO instances. For example, using the slot mechanism, it is possible to define the properties of CNs.

4. Representation and Management of LOM in ebXML Registries

4.1 Representation and Management Schemes

A learning object of an ebXML repository can be registered as an ExtrinsicObject (EO), whose special link points to the learning object. For representing learning objects, a Learning Object (LO) class is created as a specialization of the EO class. Metadata about any learning object can be directly appended to the LO instance itself using the three extension mechanisms. However, there are many elements, where each of the 9 categories in LOM is optional. In order to cope with this complexity, each category, except relation and classification, is treated as an RP. Relation and classification are respectively expressed using ebRIM associations and classifications for economic application of existing information model. The other seven categories are then classified by the LOM classification scheme, where each LOM category is defined as a CN. These classifications play the role of typing RP instances into specific LOM categories. A learning object identified by an LO instance is then an optional composition of the 7 RP instances, as shown in **Fig. 3**. Here ‘Rights1’ is classified as a ‘6.Rights’ LOM category through the Classification instance. The optional composition relationships should be managed explicitly for logical consistency. For example, deleting an EO whose objectType is LO requires removing all RO instances connected by the composition relationships. Such a composition relationship between the two ROs can only be expressed using a specific Association instance whose associationType attribute has the value of ‘composition’.

In an RP corresponding to an LOM category, most of metadata are basically expressed using Slot instances. For example, Title (1.2), Language (1.3), Description (1.4), Keyword (1.5), Coverage (1.6), Structure (1.7), and Aggregation Level (1.8) of a learning object are expressed by Slot instances. They are then aggregated into the RP instance by its 'slots' attribute. Slot instances cannot be associated with any other ROs since Slot class is not a sub-class of the RO class. Therefore, we need to devise some way to express complex relationships to be defined in each category. The Identifier (1.1, 3.1, and 7.2.1) instances are represented using the ExternalIdentifer class, whose identificationScheme and value attributes correspond to the Catalog and Entry elements respectively. For example, 'General2' is assigned an ExternalIdentifier 'ExtId2', where the identificationScheme is 'URN' and its value is 'urn:hycu:ceb021'. Identifier(3.1) is a globally unique label that identifies the metadata record itself, not the learning object.

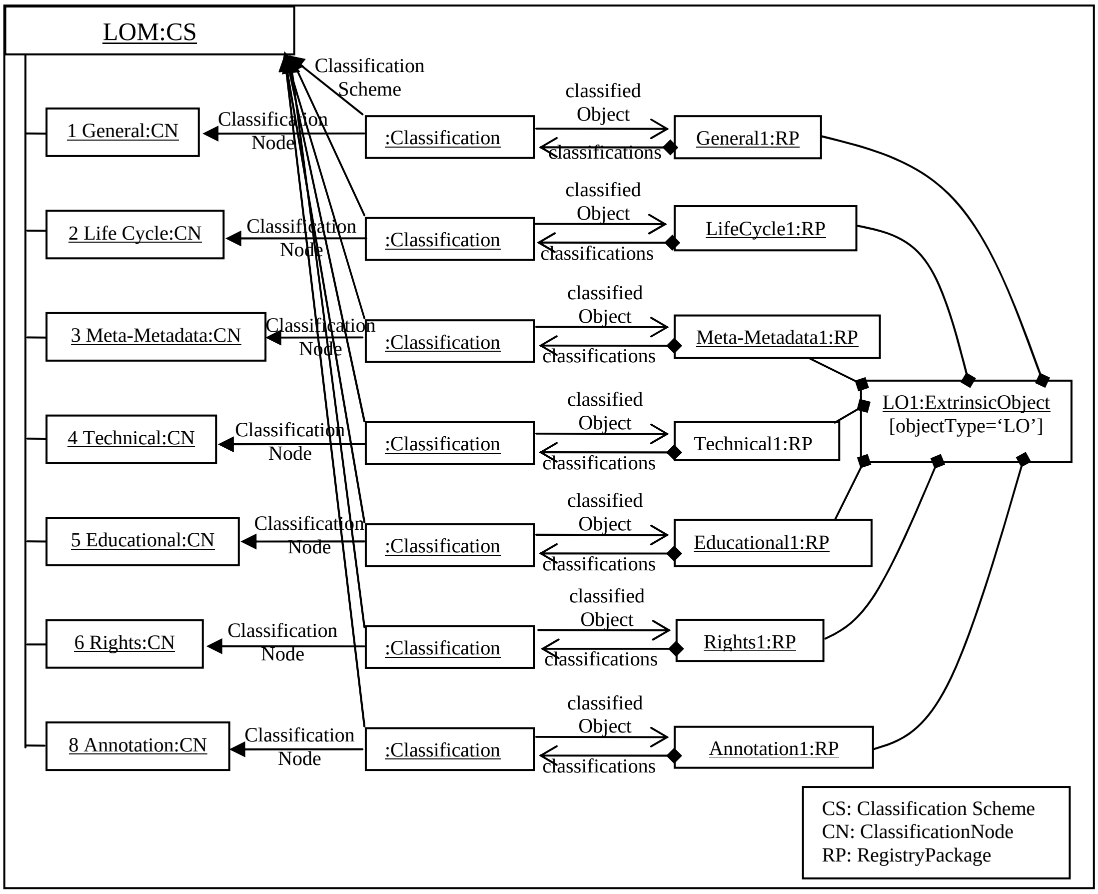

Fig. 3. LOM Objects in ebXML RIM

Relation and classification category characteristics are represented by Association and Classification instances, respectively. **Fig. 4**, for example, shows that 'LO1' is classified as 'kr' by 'ISO3166' and the purpose of this classification is 'accessibility'. Furthermore, 'LO1' has relation with 'LO2' by an Association 'isbasedon'.

The representation of Taxon Path (9.2) is similar to that of Identifier. Classification class is used for its expression. The attributes of the class are intended to allow for the representation of both internal and external classifications. A Classification instance classifies an RO instance by referencing a node defined within a particular CS. An internal Classification always references the node directly, by its id, while an external Classification references the node indirectly by specifying a representation of its value that is unique within the external classification scheme. For example, in **Fig. 4**, ‘LO1’ is classified by two Classification instances (‘C1’ and ‘C2’), which are internal and external classifications, respectively.

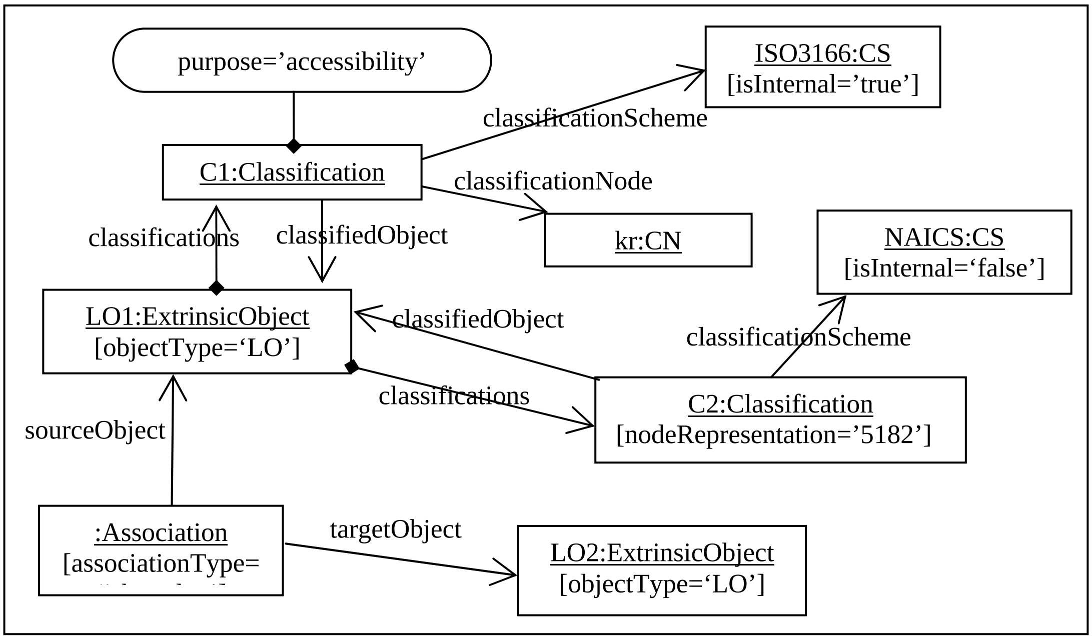

Fig. 4. Classification and association

Contribute(2.3 and 3.2), Requirement(4.4) and OrComposite(4.4.1) must be expressed as an RP instance because they group multiple properties. In the case of Contribute, each RP instance has 3 Slot instances expressing Role(3.2.1), Entity(3.2.2), and Date(3.2.3). Each RP instance is then associated with its Meta-Metadata RP instance by a ‘HasMember’ Association instance. In the case of Requirement, each RP instance has 6 Slot instances corresponding to Format(4.1), Size(4.2), Location(4.3), InstallationRemarks(4.5), OtherPlatformRequirements(4.6) and Duration(4.7). Each of them is then associated with its Technical RP instance by a ‘HasMember’ Association instance. The RP instance for Requirement(4.4) can have OrComposite(4.4.1) instances as members. Each OrComposite(4.4.1) instance has 4 Slot instances expressing Type(4.4.1.1), Name(4.4.1.2), MinimumVersion(4.4.1.3) and MaximumVersion(4.4.1.4). Here, the RP instances for OrComposite(4.4.1) play the role of making a disjunction, while the ones for Requirement(4.4) a conjunction.

In summary, e-learning objects and their semantics can be registered in an ebXML registry as follows:

(1) The e-learning object metadata ontology is stored in the ebXML registry to be used for querying e-learning objects. For this purpose, a “SubmitObjectQuery” is created by parsing the ontology and sending it to the registry, which in turn creates classification hierarchies and user-defined associations.

(2) Each e-learning object is registered in the registry as an EO. EOs point to the repository items where their contents are stored.

(3) In order to describe metadata about the EO, various types of RO instances are created according to the mapping scheme between the e-learning object metadata ontology and

ebXML RIM.

4.2 Implementation

The overall mapping scheme has been implemented using an open-source registry called freebXML [14]. Fig. 5 shows the general interface of the registry, ebRR4LOM (ebXML Registry and Repository for LOM), for creating a new registry object. Here, 'LO1' is being created as an LO (a subclass of EO). Fig. 6 demonstrates setting up an RP for the LOM General category. In the pane, there are 8 tabs (Detail, Slots, Classifications, External Identifiers, Associations, External Links, Registry Objects, Audit Trail) for providing additional information to the category. For example, the RP is classified as a '1.General' which is defined as a CN in the special 'LOM' CS of Fig. 7. Additional information for the 'General1' RP can be defined as Slot instances. ExternalIdentifiers can also be assigned to the RP. Fig. 8 shows an Association instance of 'isbasedon' type from 'LO1' to 'LO2'.

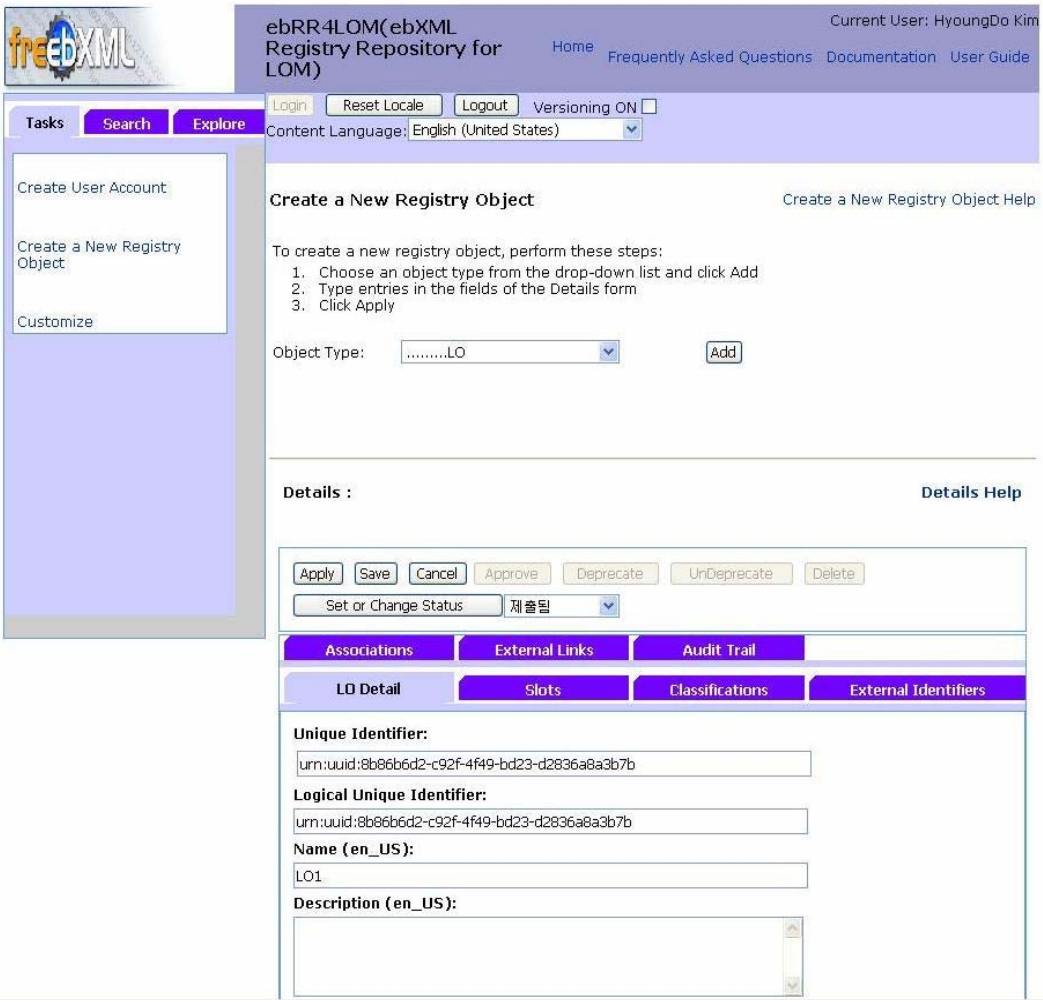

Fig. 5. Creation of a LOM object in ebRR4LOM

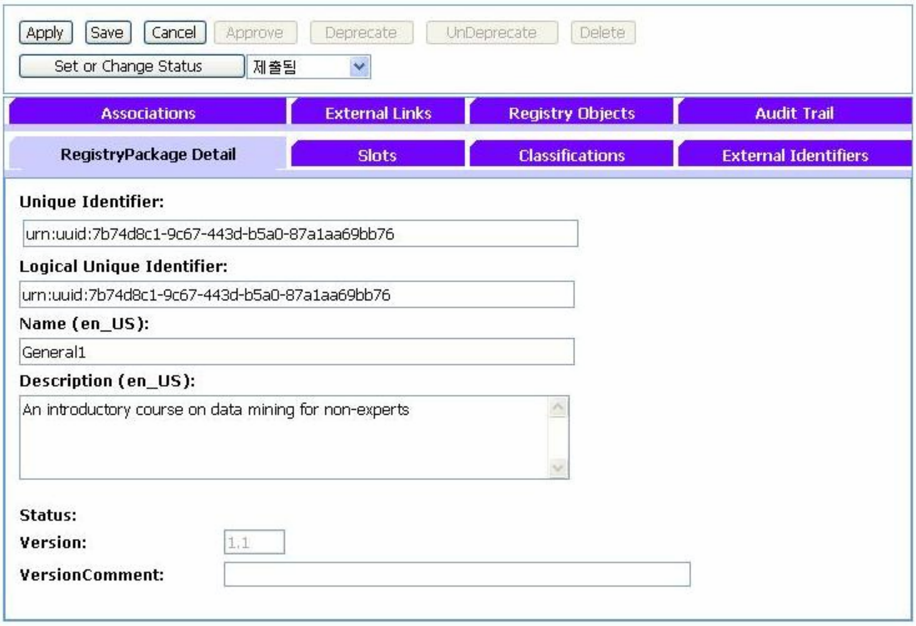

Fig. 6. Creating a RegistryPackage (RP) for the LOM General category

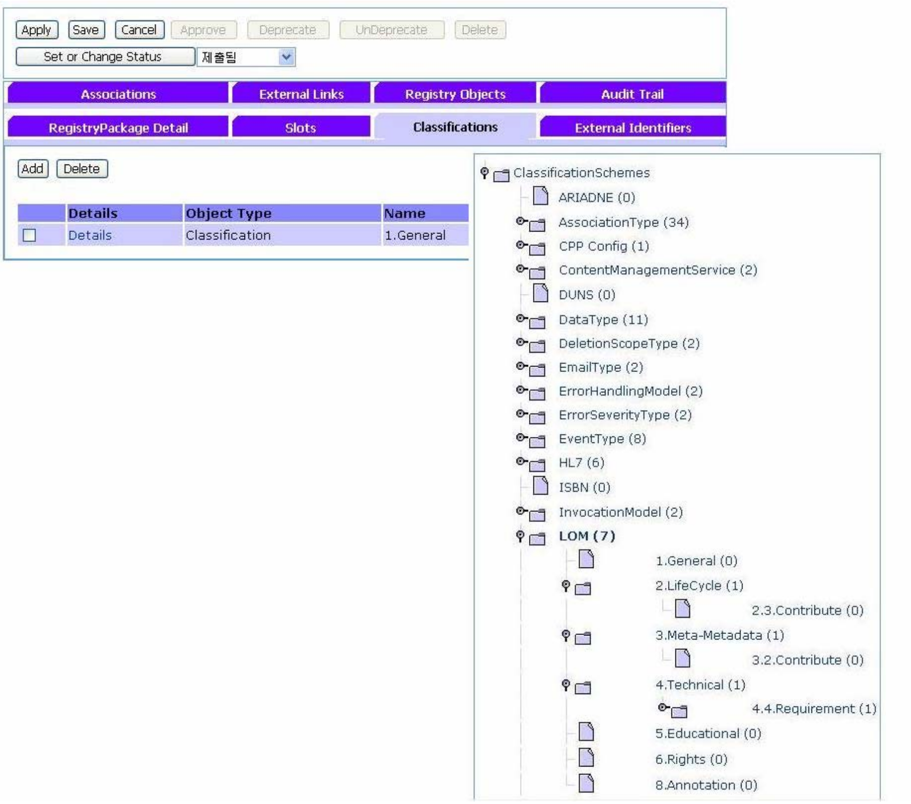

Fig. 7. Classification of ‘LO1’ as a ‘1.General’ RegistryPackage (RP)

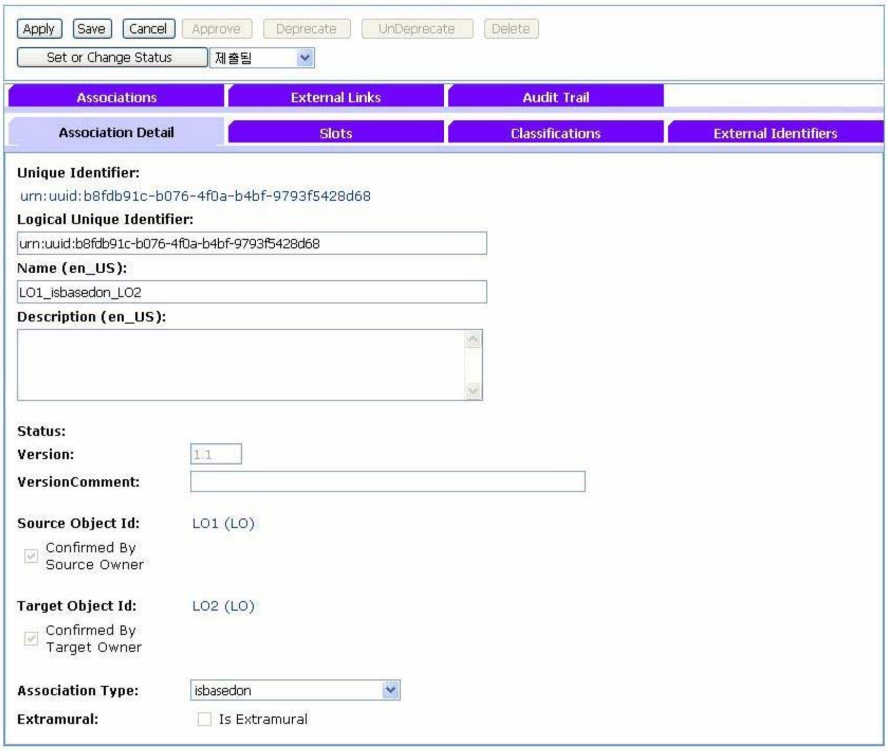

Fig. 8. Association of two LOM objects

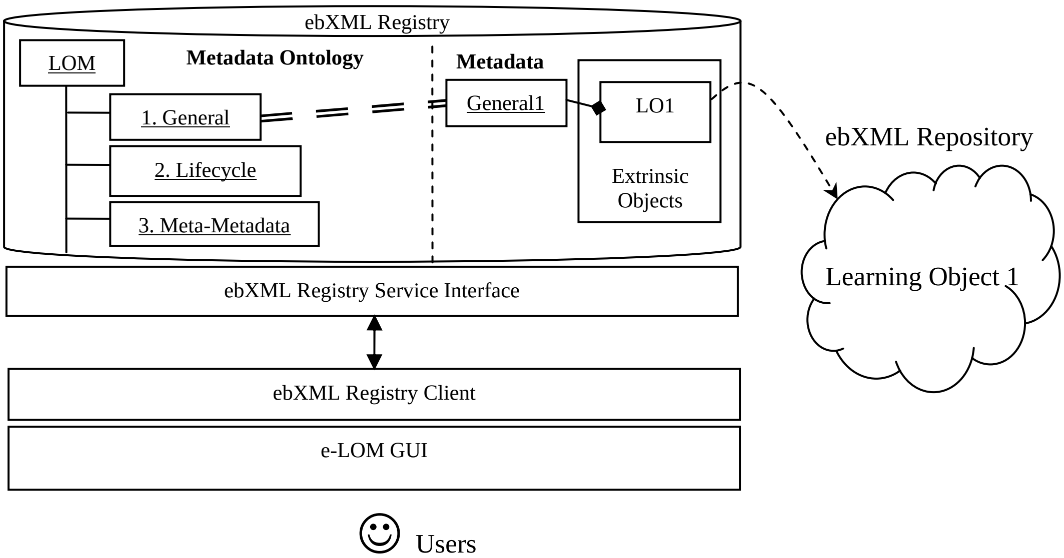

Fig. 9. e-LOM registry architecture

After storing the e-learning object along with its semantic annotation in the ebXML registry, it becomes possible to query the e-learning objects according to the metadata. To facilitate the querying of the ebXML registry for novice users, a GUI query tool is now being developed that allows users to formulate their queries by simply selecting values based on LOM as the ebRR4LOM registry architecture of **Fig. 9** shows. When a user selects values, 'Filter' queries are constructed for retrieving the identifiers of the EOs, representing the e-learning objects, according to the selected criteria. Then using the identifiers, ebXML 'GetContent' queries are submitted to retrieve the repository items (namely, e-learning objects. Note that the e-LOM GUI is located on the ebXML Registry Client. Users only view the LOM instead of ebXML RIM.

5. Conclusions and Future Directions

One solution to sharing e-learning objects in grid computing [15] is to employ public registries. This paper proposes a methodology to represent and manage LOM objects in ebXML registries. The proposed use of such registries offers the advantages of discovery and maintenance of registered content, support for collaborative development, secure version control of registered content, federation of cooperating registries to provide a single view of registered content by seamless querying, synchronization, and relocation of registered content. Although ebXML RIM is very generic and extensible using Slots and Associations, the representation and management of complex objects such as LOM objects remain difficult. In order to overcome this barrier, a mapping scheme is defined, where LOM elements are mapped to various types of RO instances. Such an ebXML registry can share all the LOM objects federated with other ebXML registries for e-learning.

Consistent use of metadata elements and vocabularies (i.e. semantic interoperability) is the key to sharing and reusing learning objects. Standard registries such as ebXML registries allow metadata implementers to publish their metadata in order to reduce duplication of effort and facilitate semantic interoperability. This approach can be very useful to many localized versions of LOM such as Korea Educational Metadata (KEM) [16], where localized vocabularies are employed. Furthermore, new needs for various adaptations or extensions are emerging in ubiquitous e-learning [17][18] and the other applications [19][20[21]. Flexible ebXML registries also shed light on this direction.

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