A Conceptual Model for Service-oriented Discovery of Marine Metadata Descriptions

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Résumé (traduit par la direction): On a décrit un modèle conceptuel qui utilise une architecture axée sur le service de la distribution des métadonnées de la marine. Le modèle utilise des normes pour la description des métadonnées et le contenu des mots clés. Pour la description des métadonnées, le modèle peut utiliser soit la norme CSDGM (Content Standard for Digital Geospatial Metadata) du FGDC (Federal Geographic Data Committee) ou la norme de l'Organisation internationale de normalisation 19115 sur l'Information des métadonnées géographiques. On obtient le contenu des mots clés dans les métadonnées structurées par l'utilisation du Répertoire de base du changement planétaire des mots clés. On a recommandé une approche décentralisée des archives pour le stockage des descriptions des métadonnées. Pour fins de communication, le modèle se réfère à une architecture axée entre des portails de métadonnées.

Introduction

There have been many marine groups working towards the 'wishful' goal of data sharing, or as it is often referred to, data interoperability. These efforts have covered the international, national and local scales. At the international level, activities typically involve the evaluation of applicable technologies and suggestions for the application of specific technologies. National efforts are usually more specific, and involve the direct application of techniques to help meet departmental data management requirements. The local efforts are typically project driven, often adopting a phased approach thereby leveraging numerous projects to meet a specific data sharing goal.

Typically, the developments resulting from these groups allow clients to access the provider's data via a network interface, such as a web browser. More recent efforts have concentrated on providing access to graphical or map representations of the data. Visual representations are extremely important for providing client familiarization with available products. As well, the map representations are very intuitive for users. However, for interoperability it is important we do not limit data usage to only visual representations. In order to achieve data interoperability, the data themselves must also be available. As well, to enable the automated fusion of data sources, there must also be quantitative metadata available to allow data discovery and utilization without human intervention.

This paper describes a conceptual model that utilizes metadata descriptions that support data discovery. The model considers national marine data management plans, and also the utilization of international metadata standards. The paper first reviews the purpose of the effort, followed by a description of applicable metadata standards and a conceptual model of how a discovery system could be constructed. The service-oriented architecture is introduced and its applicability to product delivery is described. This is followed by a discussion of the metadata and content standards needed to support the conceptual model.

Purpose

The basic concept presented here is the application of international metadata standards to aid users in the discovery of data assets. Local archives hold a wealth of marine data, but discovering these data is often a difficult process. The difficulty arises from a lack of content to be used in the discovery process and also a lack of uniform context-based searching. Presently, the best method of discovering a data asset is by using common internet search engines. However, these engines require the entry of search terms. For a successful search, the entered terms must also be those terms used in the web description of the asset. If not, the asset will not be discovered by the search engine.

The search-term problem can be alleviated through the use of metadata descriptions. Additionally, metadata descriptions that use a common metadata standard provide help beyond the search-term problem. First, the metadata description provides a descriptive layer between the asset and the client. This layer permits the mapping of asset-specific terminology to common search terms. This means that the diverse naming conventions used within the assets can remain specific to the asset, while the search criteria can use more common vocabularies. Second, the metadata description reduces the search overhead. In the marine case, the large volume of data makes it impractical for consumers to search all data in all assets in a timely fashion. Metadata descriptions should provide faster search results because of the reduced volume. Finally, the use of a common metadata standard provides consistency across data providers. The consistency allows the construction of common and automated tools for the discovery, access and mining of the content within the metadata descriptions.

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Metadata Standards

The metadata provides descriptive information about the data asset. Metadata can also provide links to the actual data asset. The delivery of data assets provides the additional problem of volume; data assets can become very large depending on the source. The delivery of the asset may be in electronic or physical form, or may only support the delivery of subsets of the asset. However, for the purpose of this report, the specific data assets are not considered. Here, we limit our discussion to metadata.

Metadata are the *values of characteristics that qualitatively or quantitatively describe or support a resource* [1]. For a data asset, the metadata would describe attributes such as who, what, when and where. A metadata standard is simply a specification of a structure designed to contain this information. The content of the structure represents the metadata description of the asset and may or may not be included in the metadata standard itself. In the process of discovery, the metadata structure performs a key role in identifying the critically important content requirements for the discovery process.

The content of the metadata description is an important component of the discovery process. The content represents the searchable terms, similar to the terms used in internet search engines. In its entirety, the content represents a summary of the data asset.

From a structural perspective, the metadata description consists of three essential parts: label, structure and value [2]. By standardizing as much as possible in all three parts, we aim to provide consistency in metadata descriptions across metadata sources. The description consistency means that common processes and software can be used to access metadata from many providers.

Standardization of the metadata label and structure can be accomplished by designing a system that uses a metadata standard. Of course, most organisations have their own standards for describing their assets. However, here we are interested in achieving data interoperability on a larger scale than a single organisation. Thus, we use the word *standard* to explicitly identify only those metadata structures which have international use. Two such standards associated with geospatial metadata exist: one from the International Organisation for Standardization (ISO) and a second from the United States Federal Geographic Data Committee (FGDC). These standards are referred to as the ISO 19115 [3] and the FGDC Content Standard for Digital Geospatial Metadata (CSDGM) [4]. These standards set the label and structure rules used to describe the data asset.

These standards are not fixed data formats. The standards may be considered outlines of mandatory and optional content, and the associated ordering of that content. The standards were developed for greatly varying application, and as such, the entire standard may not apply to every application. Organisations commonly choose to develop specialized representations of the standards, which are referred to as profiles. The profiles define a community-specific subset of labels, adhering to the structural constraints of the standard.

The United States has mandated the use of the CSDGM thus creating a large user base in both continental US and international efforts with US involvement [5]. Recent Australian (AU) efforts directed towards forming a local AU marine data community are concentrating on the ISO 19115 standard [6]. The Treasury Board of Canada is currently drafting an Information Technology Standard indicating the use of ISO 19115 as a government standard.

In terms of aiding the discovery process, the use of either standard would be a progressive step, regardless of which one was chosen. Although the ISO 19115 is the only internationally developed standard, we cannot ignore the US user base supporting the CSDGM, or the established support of CSDGM by open source and commercial metadata management tools (e.g., ISite [7]). There is also the issue of specification ease-of-use ([8] contains a brief comparison). In the longer term, there are efforts underway [9] to consolidate the ISO 19115 and CSDGM standards. This would create a single international standard under the ISO.

The decision to use a particular standard over the other needs to be made on a case-by-case basis, by considering tools, understanding of the specifications and collaborative partners. The CSDGM is widely used and at this point, contextually better understood. It is also easily accessible in many metadata authoring environments. However, the end goal for the US and Canada will be the adoption of ISO 19115.

Given the difficult choice between standards, some projects are attempting to provide consumers with either metadata description. In the United Kingdom, the NERC DataGrid (NDG) project has developed a meta-metadata structure [10]. The NDG structure contains the content required to create either the ISO 19115 or the CSDGM structures.

For the architecture described here, either metadata standard will provide sufficient data asset descriptions for the marine community. In fact, individual provider sites could use either standard, with communication between sites providing the necessary transformation of search criteria to meet the requirements of the individual standard (although the reader should recognize these transformations are nontrivial). Thus, we recommend the use of one of these standards but do not favour one standard over the other. Local and community efforts also play a critical role in the decision, thus making it difficult for the authors to identify a single solution.

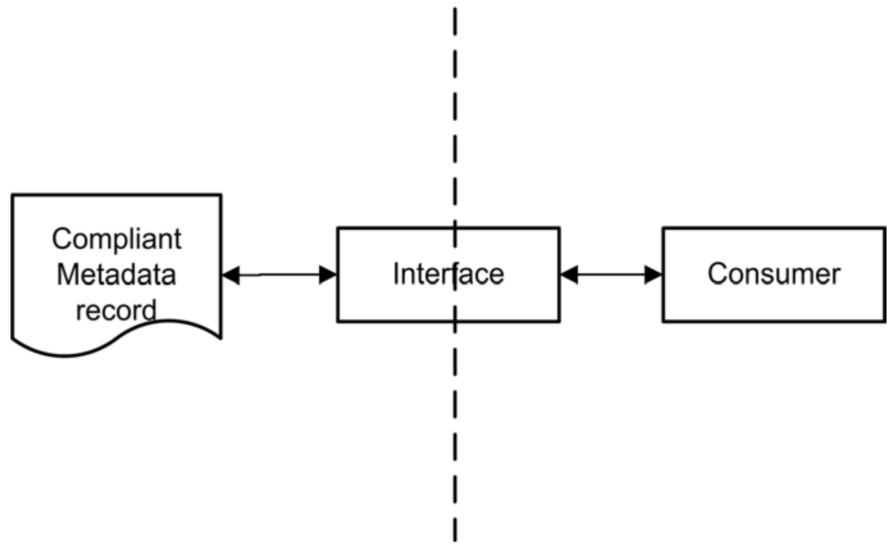

Figure 1: The conceptual model for metadata delivery. The metadata are created at the data source location. The consumer accesses the metadata through an interface that understands both the consumer requests and the system containing the metadata. The distinction between the consumer access side and the infrastructure tier is denoted by a dashed line.

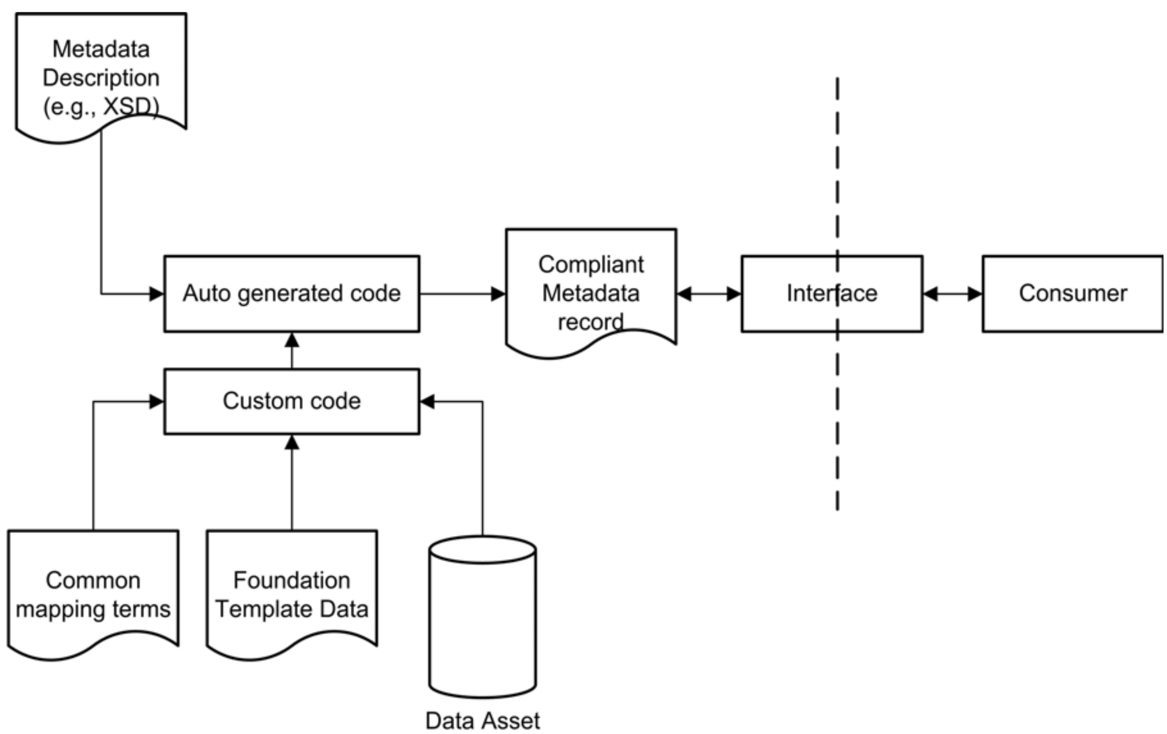

Figure 2: The conceptual model for providing metadata descriptions. The explicit metadata description, represented as a document type definition (DTD) or XML schema definition (XSD) document, is used to automatically generate code. Custom built code is used to access the data, foundation template data, and the mapping of data type terminology, combining the sources and describing the data asset in a standards-based metadata description.

Vocabularies Defined within the Metadata Standard

As noted previously, the content of the metadata structure represents the metadata description. The permitted content for a specific metadata attribute is defined as the domain of values for the attribute. The domain can be restricted by type (e.g., character) but remain unrestricted in form (e.g., free text). Domains can also be restricted by using lists of allowed values. For example, the CSDGM standard contains a metadata attribute for "progress", referring to the progress made on processing a data asset. The allowed list of values for "progress" is: "Complete", "In work", and "Planned". This list of values represents a vocabulary defined within the standard. This is a form of a controlled vocabulary. Note that this vocabulary is defined within the metadata standard. However, vocabularies may also be defined external to the metadata standard.

Vocabularies Defined External to the Metadata Standard

Each data provider typically has a unique vocabulary that is often an integral part of their data asset. The vocabulary provides a naming for the specific content of the asset. However, the vocabulary is often unique to the data provider. Control of this vocabulary is maintained by the provider, often because the vocabulary is used within the local processing systems.

As noted previously, metadata content provides a descriptive layer between the asset and the client. This layering provides the opportunity to use a different vocabulary to describe the contents of the asset, as compared to the vocabulary within the asset. The use of a different vocabulary does introduce a requirement for a mapping between vocabulary terms. Such mappings can be difficult, due in part to the exact and explicit requirements of the mapping, both of which are required to ensure interoperability between data assets.

For the current discussion, consider the use of two external vocabularies; one vocabulary used within the data asset and a second used within the metadata description. If the purpose of the metadata description is discovery of the asset, then the vocabulary in the metadata description may be called a discovery vocabulary [11]. A discovery vocabulary typically contains common language terms (e.g., "sound velocity"). These terms are often referred to as keywords. There is typically a non-rigorous definition associated with the keywords.

The collection of terminology associated with individual data items within the asset may be called a usage vocabulary. This terminology may be a cryptic code (e.g., "SVEL") that is unique to the providing data set. There is typically a rigorous definition associated with each term in the usage vocabulary. As well, it is typical that many terms in the usage vocabulary map relates to a single term in the discovery vocabulary.

It is important to use a discovery vocabulary in the associated metadata records rather than the usage vocabulary. This is because searches will utilize common language terms as opposed to the often cryptic terminology used in a usage vocabulary. Discovery vocabularies are very well suited for discovery of assets from Internet portals, and for this reason are considered in this model.

One well-recognised discovery vocabulary is the Global Change Master Directory (GCMD). The GCMD vocabulary was first offered as a keyword list in 1995. This vocabulary is also being suggested for use in a Canadian code-mapping exercise (more in the next section), for use in a collaborative Canadian-Australian data asset discovery system, and is also noted in keyword examples in documentation of the US Integrated Ocean Observing System (IOOS) [12].

The GCMD specification appears in wide use in the marine community. However, GCMD topics cover a wide range of categories (e.g., agriculture, atmosphere, human dimensions, land surface, etc. [13]) and thus can be applicable to many domains. Thus, we consider the use of GCMD terminology as a reasonable choice for the discovery of data content. Either metadata standard can accept GCMD terminology using the theme key elements. If providers wished, they could also include details on the particular usage vocabulary. In the CSDGM, this would take the form of an entity description while in the ISO 19115 it would be contained in Content Information.

Conceptual Architecture - Decentralized and Service Oriented

The standards and vocabularies noted above are used to build the metadata descriptions. From the descriptions, we can begin to form a conceptual model using three critical components: the metadata description, a consumer, and an interface between the metadata and consumer (Figure 1).

The metadata description may be created through manual process, where staff familiar with the data asset digitizes the required metadata content. However, this would be slow and inefficient. Ideally, compliant metadata descriptions would be created in an automated fashion using the data assets as input. The automated process could use a combination of automatically generated and custom developed software (see Figure 2).

The automatically generated software would provide developers with easier access to the individual data elements in the metadata structure. Generation tools, some of which are open source and freely available (e.g., The Castor Project [14], Zeus [15]), read formal definitions of the metadata structure and create software that interfaces with the structure. The formal definitions are typically described using the eXtensible Markup Language (XML) document type definition (DTD) or XML schema definition (XSD). The customized code would then utilize the auto-generated code to provide the content to the metadata structure elements in XML.

The custom built code has two other important inputs: the foundation template data and the mapping to a common vocabulary. The foundation template data contains quasi-static data asset metadata that is required in the metadata description. For example, metadata descriptions often contain an abstract that describes the asset. Such abstracts are often not part of the data archive. As well, the abstracts are somewhat static, in that they do not typically change with updates to the archive. The abstracts associated with data assets are an example of foundation template data. Other examples include the individuals or organisations identified as contacts for data asset information. The foundation template data would be created once and stored separately from the data, and reused to populate applicable elements either from within entry tools or automated processing.

The mapping to a common vocabulary is also quasi-static. The mapping stores the relationships between the organisations usage vocabulary and those terms defined by the discovery vocabulary. This is an essential part of the final metadata description, as it provides commonality of data type naming. The commonality allows automated searching to be based on a common vocabulary, even if the local data asset utilizes a local usage vocabulary.

There is an effort underway at the Canadian Integrated Science Data Management (ISDM, formerly the Marine Environmental Data Service, or MEDS) to manage the vocabulary mappings at the national level. In Canada, a formal mapping exercise took place as a result of a collaborative Department of National Defence and Fisheries and Oceans effort to define an XML-based structure for data exchange [16]. This mapping effort utilized data vocabularies from the Institute of Ocean Sciences, Bedford Institute of Oceanography and MEDS. This initial effort, combined with the present more formal effort underway at ISDM, can form the basis of the mapping requirement described here.

The single interface shown in Figures 1 and 2 may suggest a single access point for consumers to acquire the metadata descriptions. A single access point suggests (although not always the case) a central authority and perhaps a central archive for the management of the metadata descriptions. However, the figures may also represent one node of a decentralized model.

Both the centralized and decentralized archive models offer certain advantages. The centralized archive model offers resource savings, as only one location needs to manage the services. For example, only the central archive would need development and maintenance of the software that provides the service, or the supporting infrastructure including hardware and backup functions. However, for sustainability the centralized model requires a contiguous line of authority and responsibility from the data provider to the central archive. Alternately stated, the data provider needs the ability to directly influence the central archive (the opposite is also true). Otherwise, the central archive can alter its management functions without considering the data providers.

Central archives also have administrative issues related to such things as governance, collaboration and protected information. An example of governance issues includes things like a lack of response by the central authority to identified problems. Again, this is often a result of data providers having no line of authority within the central archive. Central archives may also place restrictions on the autonomy of local providers, by mandating requirements based on the existing systems at the central archive. There may also be issues related to private or protected information, where distribution to an archive outside the organisation is not permitted, but where metadata descriptions are still useful for internal usage.

Within an organisation or managerial unit, the centralized model can work effectively. However, the contiguous line of authority is broken when considering inter-departmental or international collaboration. When the line of authority is broken, a decentralized model is more sustainable.

A decentralized model relies on a distributed set of nodes. The cornerstone of decentralization is the implementation of standards, where each node provides access to a set of services in a structured, defined and consistent manner. In this case, the services provide access to the metadata descriptions.

Decentralization allows the metadata description to remain local (or closer) to the data provider. In fact, the metadata description remains within the authority line of the data provider. Thus, the decentralized nodes that span inter-departmental or international boundaries could form individual centralized nodes within independent organisational units. Effectively, the centralized archive for an organisation is one node in a decentralized set of nodes.

In this type of hybrid model, the metadata description remains closer to, and within direct line of authority with, the data provider from which it originated. As well, decentralization allows other organisations, which are compliant with the implementation standards, to contribute to the set of decentralized nodes. This aspect allows collaboration from unexpected sources.

In the past, the decentralized model has been technically difficult while the centralized model has been much easier to implement. For example, product delivery to a central archive could take the form of an attachment to an email message, or as an ftp-style GET or PUT function between parties. However, this type of delivery is labour-intensive, involving staff to physically deal with the delivered product. Harvester software was then developed to reduce the staff requirements, automating the delivery process. However, harvester software often has issues associated with the opening of specific computer ports, which in turn has implications for firewall administration and local and/or national computer security policy.

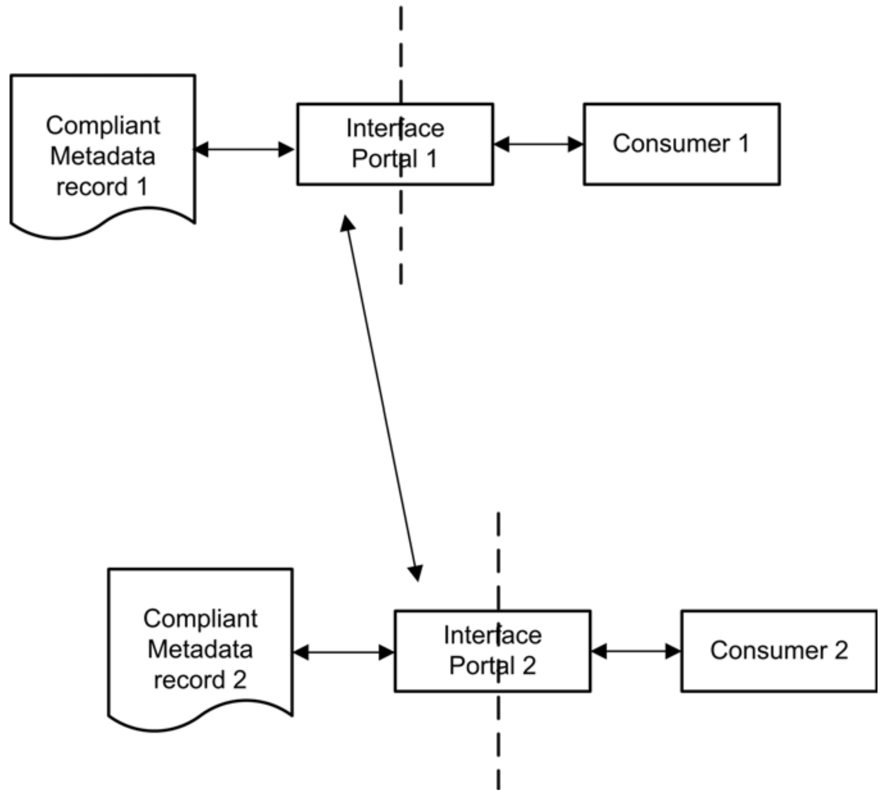

Figure 3: In the decentralized model, Consumer 1 and Consumer 2 can search both metadata descriptions regardless of the Interface entry point.

Fortunately, the development of service-oriented architecture (SOA) allows a much easier joining of the centralized archives into a decentralized set of archives. In the simplest of terms, a service-oriented architecture supports computer-to-computer interactions, with the interface to the available services being described in a computer processible form. Queries to and results from the service can be delivered over hypertext transfer protocol (HTTP), and are also processible due to service communication standards (e.g., Simple Object Access Protocol, or SOAP). The automation aspect of SOA nullifies the staff requirement, while the HTTP communication aspect nullifies the computer security issues associated with more traditional harvester software. In effect, SOA provides a technical solution with administrative benefits.

The implementation of SOA in a decentralized model has an additional benefit. The SOA easily allows communication between interfaces (Figure 3). In this approach, the interfaces become what are referred to as Portals. Portals communicate with one another, providing the consumer with seamless access to the products at all the inter-connected provider sites. As well, this type of architecture allows redundancy in consumer entry points, while the central model has a single entry point and thus a single point of failure.

Summary

The conceptual model presented here highlights four important points related to marine metadata descriptions. First, we recommend the use of a geospatial metadata standard, either the ISO 19115 or the CSDGM. The metadata descriptions are well-suited to an XML structure as this allows use of available tools. Second, we recommend the use of GCMD keywords as the basis of the discovery vocabulary. The GCMD keywords provide an English language description of data types in the archives. This permits the usage of more common search words for the discovery of the data asset. Third, we recommend a decentralized architecture built from centralized archives that exist within contiguous lines of authority in an organisation. This type of architecture provides benefits such as easily allowing participation of other interested organisations and access-path redundancy. Finally, we recommend the use of a service-oriented architecture as the basis of the communication mechanism between organisational-based nodes.

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(U) A conceptual model that utilizes a service−oriented architecture for marine metadata delivery is described. The model employs standards for metadata description and keyword content. For the metadata description, the model can utilize either the Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata (CSDGM) or the International Organization for Standardization Geographic Information Metadata Standard 19115. Keyword content in the metadata structure is achieved by using the Global Change Master Directory of keywords. A decentralized archive approach for the storage of the metadata descriptions is recommended. For communication, the model relies on a service−oriented architecture between metadata portals.

(U) Nous faisons la description d'un modèle conceptuel utilisant une architecture axée sur le service pour la distribution de métadonnées marines. Le modèle utilise des normes pour la description des métadonnées et le contenu des mots−clés. Pour la description des métadonnées, le modèle peut utiliser soit la norme de contenu des métadonnées géospatiales numériques (Content Standard for Digital Geospatial Metadata) du Federal Geographic Data Committee, soit la norme 19115 sur l'Information géographique – Métatonnées de l'Organisation internationale de normalisation (ISO). Le répertoire GCMD (Global Change Master Directory) est utilisé pour déterminer le contenu des mots−clés dans la structure des métadonnées. Une méthode d'archivage décentralisée pour le stockage des descriptions des métadonnées est recommandée. Quant à la communication, le modèle se sert d'une architecture orientée service entre les portails des métadonnées.

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(U) service orient architecture; SOA; metadata; ISO 19115; Global Change Master Directory; Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata; vocabulary