GeoDRM: Towards Digital Management of Intellectual Property Rights for Spatial Data Infrastructures

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ABSTRACT

Web services are the building blocks of the modern spatial data infrastructure (SDI). Ubiquitous sharing and exchange of geospatial content and services is hampered by potential infringement of the intellectual property rights (IPR) of providers and producers. Proper management of IPR is a serious challenge that we face with the establishment of geospatial information commons and marketplaces. Recently, the Open Geospatial Consortium (OGC) established a geospatial digital rights management (GeoDRM) working group. The general objective of the working group is to define trusted infrastructures to protect rights to digital geospatial content. The GeoDRM working group also aims at facilitating the adoption of DRM as a technology for dissemination and management of IPR in the geospatial domain. In this article we present a novel approach to GeoDRM by providing a GeoDRM architecture based on our research into the current nongeospatial DRM technology. The adoption of DRM technology into the geospatial domain will enable the management and licensing of IPR on geospatial assets while keeping the effort of developing unique GeoDRM technology at a minimum. We also address the essential information model that is required for GeoDRM digital licensing to function. The model is based on our previous analysis and research into DRM information models for nongeospatial assets. This information model provides a technology-neutral information view of the requirements of digital licensing of geospatial assets. The GeoDRM policy of a given organisation relies on both a technical framework and a legal framework. This article does not address legal frameworks, because they are dependent on the organisational context in which GeoDRM technology is implemented. GeoDRM is in the early stages of development, and we propose a research agenda that we believe is necessary to further GeoDRM development and adoption within the geospatial community.

INTRODUCTION

As technology pushes various industries toward the digital frontier, many types of content are becoming available solely in digital format, and geospatial data is no exception. Copyright-protected geospatial content used to be sold on paper sheets but is now available in digital format. As a result, such content can now be used by a variety of users and devices: from car navigation systems, handhelds, and mobile phones all the way to corporate applications and business-related geospatial functions. Digital geospatial datasets moving across computer networks can be easily copied, transformed, or incorporated into new value-added products and services. Geospatial-data producers and owners are faced with the challenge of controlling the dissemination of their digital geospatial assets downstream in the geospatial value chain.

Onsrud et al. (2004) argue that the desire of producers for proper intellectual property rights (IPR) management is driven not by monetary gain but rather by the moral rights associated with the use of spatial data. The author's rights to have his assets used in an appropriate manner and the recognition gained from that are important issues for the establishment of the public geoinformation commons.

Digital rights management (DRM) is a popular term for a field that came into being in the mid-1990s. Two basic definitions of DRM exist: a narrow one and a broad one. The narrow definition of DRM focuses on persistent protection of digital content. It allows the distributor of data to control how the data is used, and by whom, in accordance with predetermined rules and agreements. The broad definition of DRM encompasses everything that is required to define, manage, and track rights on digital content. In addition to persistent protection, the latter definition also includes business rights or contract rights and access tracking. DRM solutions in the broad sense are potentially capable of tracking access to and usage of operations on content. Information about usage is often inherently valuable to content providers, even if they do not charge for the usage of content (Rosenblatt and Dykstra 2003).

Recently, higher awareness of IPR problems within the spatial data infrastructure (SDI) community gave rise to the discussion of the challenges surrounding the management and dissemination of data. Open Geospatial Consortium (OGC) formed a geospatial DRM working group (GeoDRM WG) with the mission of adopting the work done in the area of data ownership and digital rights management to the geospatial community. The working group addresses the lack of GeoDRM capability as a barrier to wider adoption of Web-based geospatial technologies. In this article we define the general components of the GeoDRM framework with a focus on the technical aspects of GeoDRM. We describe the GeoDRM architecture as a high-level architecture of loosely coupled services that manage digital licensing functionality for GeoDRM based on the study of current digital licensing infrastructures. We also discuss the GeoDRM information model, which is a technology-independent information view of the elements needed for a GeoDRM architecture to function. Both the architecture and the information model are based on proven and available DRM technology.

GeoDRM DEFINITION AND SCOPE

GeoDRM is defined as a set of technologies and legal frameworks that are fit for a certain organisational need, enabling rights-managed geospatial networks (e.g., SDIs), where all rights over geospatial assets are specified by licensors and any licensee would be "trusted" to honour the licensor's conditions within and beyond the network's trusted environment (e.g., remote clients). In this definition, trust is not synonymous with "enforcement of digital licenses," which in turn might or might not be part of a certain GeoDRM framework. In addition, a legally binding framework of licenses and licensing policies that are mapped to digital equivalents must support GeoDRM. This makes a GeoDRM license a legal tender that must be respected.

An asset is defined in Webster's dictionary as "an item of value owned." In the realm of service-oriented architecture (SOA), an organisation can own the rights to a service rather than digital content. Hence, the value attribute may apply to services as well. In this sense, we use the term asset to refer to both digital geospatial datasets and services in an SDI.

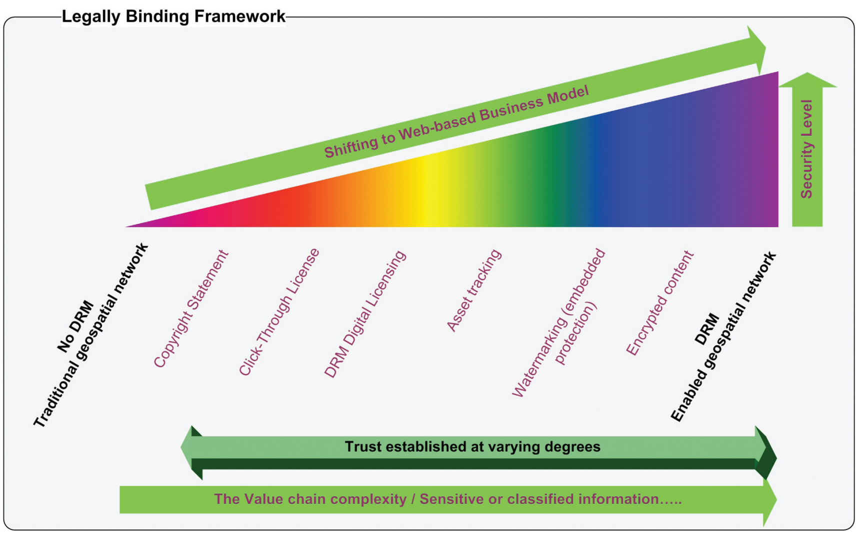

Figure 1. The elaborated GeoDRM spectrum (Vowles and McKee 2005).

Vowles and McKee (2005) provide an interesting perspective on GeoDRM as a spectrum of technologies. Figure 1 shows an elaborated version of this GeoDRM spectrum:

- As business models change according to organisational needs, so do the GeoDRM schemata used to disseminate IPR. SDIs like INSPIRE opt for click-through licensing for most of the data themes covered by the initiative, while Ordnance Survey UK Master Map already has click-through licensing and is opting for digital licensing and tracking of its assets.
- The modern SDI relying on SOA provides a stimulus for more sophisticated techniques of IPR management.
- For the SDI to support higher security models and access rights, more sophisticated GeoDRM technologies are needed.

- The legal framework is inseparable from the technical framework in GeoDRM, and together they form the essential GeoDRM policy. GeoDRM implementations will use a combination of the technical and legal tools to achieve the desired level of IPR management within an organisation.
- Trust is an essential component of GeoDRM and is an explicit reflection of the moral aspects of IPR law. In a geospatial data-sharing environment, a number of institutions explicitly admitted to sharing data freely with people they know and trust, while making it difficult for others outside their circle of trust to gain access (Harvey and Tulloch 2004). Additionally, Harvey (2003) argues that trust is important for geospatial data sharing. As geospatial information and maps are replacing experiential knowledge (e.g., "I trust that this map is accurate and will base my decisions on it"), establishing trust in geospatial data-sharing environments is essential. GeoDRM assures parties of each other's identities, and the preservation of their IPR increases trust in the data-sharing environment.

To illustrate how the GeoDRM spectrum can be implemented, geospatial digital watermarking can be used to track misuse of digital assets by identifying the sources of infringement. Thus, a combination of digital licensing and watermarking can assist geospatial-data providers in an SDI with monitoring the usage of their assets for the correct purpose. Once a watermarked dataset is found in a usage scenario where it shouldn't have been used (i.e., a map watermarked for user X being used by user B), the providers can trace back the source of infringement and minimise the damage to their intellectual property. This ability to combine technology (digital watermarking) with the correct legal actions to achieve the optimal degree of IPR management across the SDI is among the future research challenges for GeoDRM.

GeoDRM ARCHITECTURE

In this section, we present an overview of the proposed GeoDRM architecture. We first provide a brief description of DRM services by examining the general DRM reference architecture and the digital licensing infrastructures that are common amongst most DRM systems. We then show that, from a digital licensing perspective, DRM systems and GeoDRM are not fundamentally different, since they both manage licensing of digital assets, no matter how different those assets might be. We also discuss an approach for adopting current digital licensing and DRM technology into the geospatial domain to leverage already established and tested technology.

DRM. Rosenblatt et al. (2002) introduced a general high-level DRM reference architecture that is widely adopted in the DRM domain. The DRM reference architecture includes the most relevant components in DRM systems. It includes a publisher service that provides the original asset and provides facilities for delivery to the client. The licensing server is the administrative hub of the digital licensing server. It brokers negotiations between vendors and consumers and grants licenses. The licensing server generates the digital license, and the publisher attaches it to the asset being sent to the client. The recipient or the client has a controller service which receives the user's request to exercise certain rights on the content. The controller acquires the user's identity information and obtains a license from the license server. It then retrieves the encryption keys from the license, decrypts the content, releases it to the rendering application, and executes the license terms.

For management of digital licensing, more advanced architectures have been proposed. We follow the digital licensing infrastructure model of Thompson and Jena (2005). The digital licensing infrastructure enables machines to negotiate and issue licenses to protect assets and to regulate how assets and licenses are sold or used. The infrastructure also enables asset holders to track and monitor compliance with terms and conditions of use. The components of the digital licensing infrastructure are described in the context of the GeoDRM architecture below. This digital licensing infrastructure is designed to manage licensing of content and services in a variety of settings. We believe that GeoDRM would require such complex licensing capability.

We have established that the GeoDRM architecture for digital licensing should not be fundamentally different from that of other DRM, since digital licenses are what is being managed. Although geospatial licenses would differ to a degree from other types of digital licenses, from a broad perspective the differences between the two architectures will likely be minimal. Hence, by building on existing DRM technology, we leverage DRM into GeoDRM by creating a GeoDRM architecture for digital licensing of geospatial datasets.

GeoDRM. Figure 2 illustrates a formal UML (Unified Modeling Language) component diagram of the high-level GeoDRM architecture. The diagram combines the functionalities of DRM architectures (Rosenblatt et al. 2002) and digital licensing infrastructures (Thompson and Jena 2005). The GeoDRM service acts as the workflow hub of the GeoDRM system and coordinates the interactions between services, while the GeoDRM client component has the responsibility of managing licensing-related client side interactions with the GeoDRM service. The GeoDRM service can be located in the geoinformation publisher's environment, but it could also be a third-party trusted license provider service.

The data discovery service will provide one or both of the following solutions:

- **Extended CSW.** An OGC Catalogue Service for the Web (CSW) (OGC 2002) specification supports the registry and discovery of geospatial information resources. A CSW plays the role of a directory in the open distributed Web service environment, and it also allows data and service providers to register their capabilities using metadata, which users can query to discover information of interest. The metadata defined in the CSW could be extended so that users can search for data based on GeoDRM-related keywords (e.g., to see if the extracting feature is permitted). This will play a central role in the discovery process, where service metadata must express relevant GeoDRM metadata criteria (e.g., service requires prelicensing or licensing occurs after the data is released).
- **Product catalogue.** A provider's product catalogue would specify several licensing schemata mapped to assets so that a negotiation service (described below) can negotiate terms with users. Each license would be dynamically generated for a selected product.

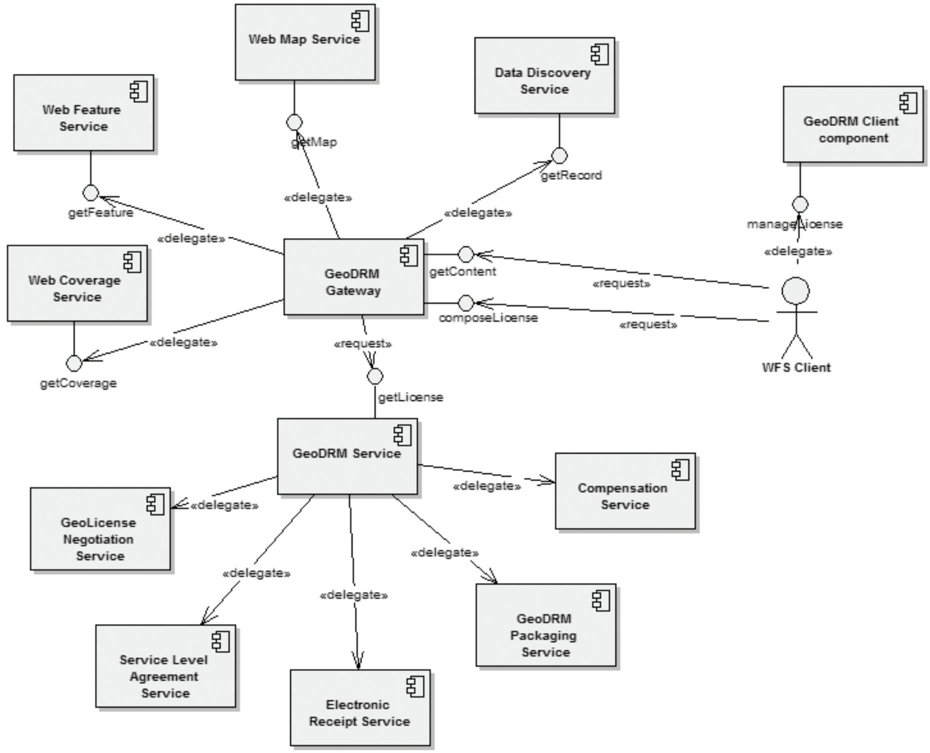

Figure 2. GeoDRM architecture in a UML component diagram.

Other GeoDRM specialised services are as follows:

- The **GeoDRM packaging service** packages a geospatial dataset file or stream with its license and, if requested, encrypts the stream of files at run time before dispatching the package as a geospatial object.
- The **service level agreement service** defines an optional section of a license. For certain service types (i.e., mission-critical or emergency) some licenses would contain penalties and service level parameters. A vendor might agree to pay a penalty for performance below some quantified level of service or acknowledge legal liabilities.
- The **compensation service** defines a compensation scheme and a method of payment. License servers would use compensation models such as pay-me-now perpetual or term-limited licenses (the consumer purchases a license for use of a given object over a specified time), pay-per-user licenses (the license server generates license keys based on the number of stand-alone applications purchased), and pay-per-use or subscription licenses (the consumer purchases units of usage of some asset, so a license key is generated every time the service is invoked).
- The **electronic receipt service** generates a persistent log entry (e-receipt) for each purchase or use of an asset. This e-receipt records which services were used and the form of payment. The service can generate e-receipts for

geospatial Web services usage, client interactions, calls to a geospatial database, or datasets purchased over the Internet.

- The **geolicense negotiation service** provides offers and counteroffers between vendors and consumers until they reach an agreement (translated into a digital license). Negotiation can be manual, semiautomatic, or automatic; the service in the manual case would act as a facilitating medium of contact between the two parties involved.

In the GeoDRM architecture, we define two main use categories: (1) protecting and publishing an asset and (2) searching for and acquiring an asset.

In data publishing, providers perform the following tasks:

1. Define license terms and pricing schemes for services and content published in an SDI.
2. Create the appropriate Right Expression Language (REL) profile schema to support custom needs by means of management tools.
3. Publish the REL profile schema on the GeoDRM system.
4. Create metadata using the SDI metadata profile which has an extension to search datasets based on right descriptions as specified by the REL licenses.

In asset search and acquisition, users (asset consumers) perform the following tasks:

1. The user accesses the catalogue service on the SDI and searches for certain data offered by vendors who can provide licenses suitable for the user's needs.
2. The catalogue returns to the user the needed data.
3. The user interacts with the GeoDRM system where a data provider is registered to acquire the license and data.

Once users locate the required data, they send a request to the GeoDRM gateway, which in turn forwards it to the GeoDRM service. The GeoDRM service interacts with the services that hold the data to generate the custom license for the requested asset. The actual sequence of interactions between GeoDRM clients, the GeoDRM system, and the data provider may vary from one implementation to the other. The following three cases show different interaction flows from data suppliers to users.

Case 1 (figure 3) is most suitable for situations where data acquisition from a certain service requires users to have a valid usage license. In this scenario, possession of a license is a prerequisite to acceptance of data requests.

Case 2 (figure 4) is most suitable for users who already have the data but need to upgrade or modify their license terms. For example, a user may have rights to a dataset for noncommercial use and requests a license for commercial use.

In case 3 (figure 5) users interact with the GeoDRM gateway, which ensures a proper workflow, to request both data and a license from a provider according to the provider's business model. Also the Web Feature Service (WFS) is assumed to be extended to allow for relevant GeoDRM functionality. For example, each dataset sent must have minimal instructions for where to obtain licenses (e.g., the licensing server URI [Uniform Resource Identifier]).

Irrespective of the specific implementations of the three cases above, separating the license and the data is important. In earlier DRM systems the data and the

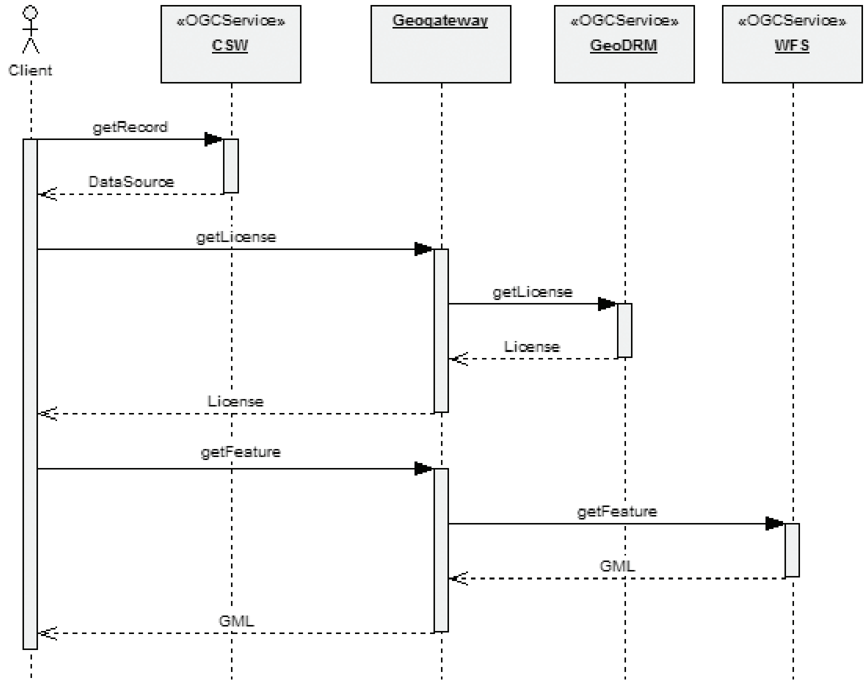

Figure 3. Case 1: license first and then release data.

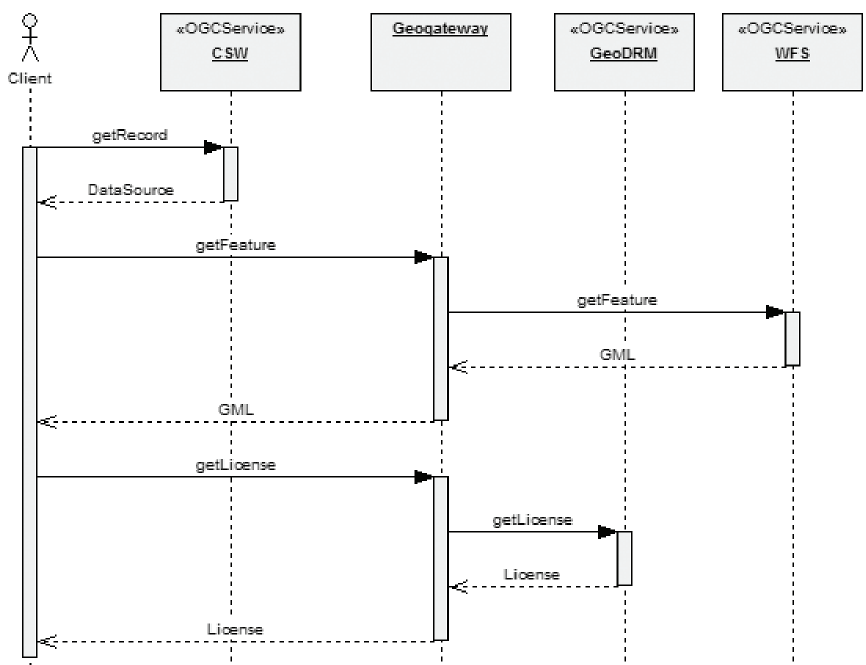

Figure 4. Case 2: data first and then license.

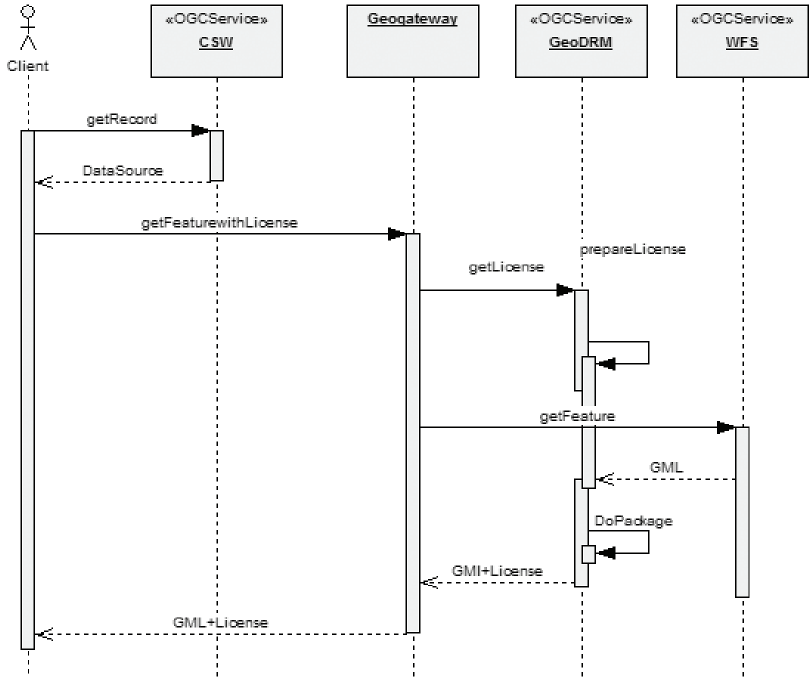

Figure 5. Case 3: data and license combined.

license were hardwired together (Rosenblatt 2002). This model would not have enabled cases 1 and 2. By decoupling licenses from data, GeoDRM technology allows users to negotiate unique terms instead of relying on a static license schema.

GeoDRM INFORMATION MODEL

A license data model is specified by Right Expression Language (REL). This means that the structure of the language schema and its semantics would determine the exact implementation of the data model. However, the language needs to be extended for GeoDRM, and a conceptual information model needs to be developed. The GeoDRM information model described below is independent of any REL or technology implementations.

Figure 6 illustrates the general GeoDRM license information model. A license can be assigned to various asset types (individual features, feature attributes, or feature types). The elements of the GeoDRM information model are as follows:

1. Rights information: a definition of types and meaning of the permissions granted in a license (this includes spatial- and nonspatial-data permissions and how they are expressed).
2. Rights constraints: a definition of the types and meaning of spatial- and nonspatial-data constraints that may apply to each permission (principal or resource).

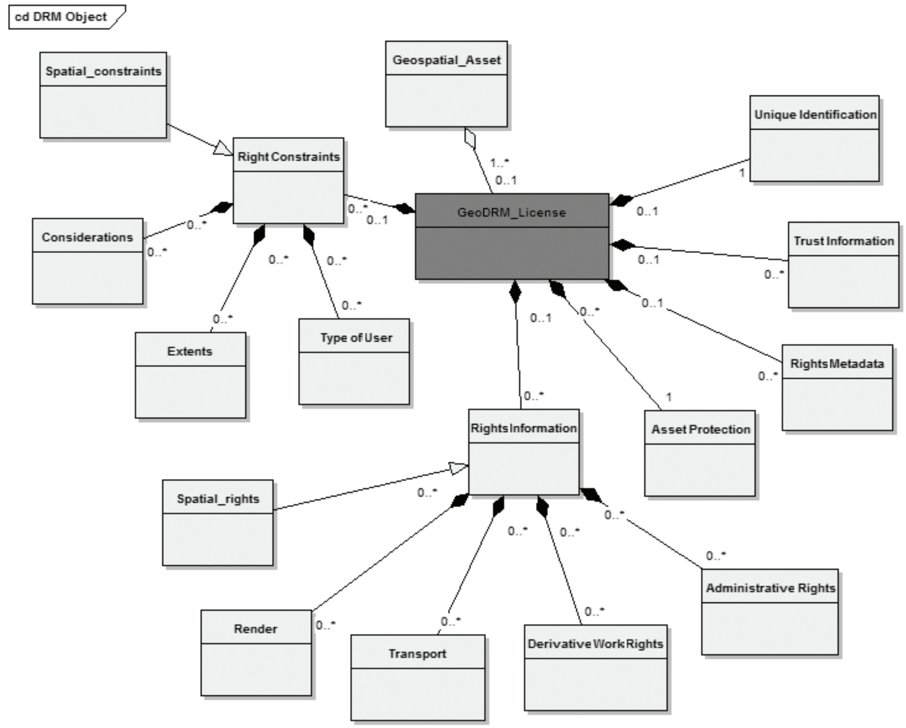

Figure 6. GeoDRM information model.

3. Unique identification (1) provides necessary unique identities to geospatial-asset holders and licensees in an open distributed environment like the Web and (2) enables licenses to refer to assets being managed.
4. Rights metadata: general information to enable the search and discovery of assets in a Web environment based on certain GeoDRM criteria (e.g., rights).
5. Trust information: authentication of identity and verification that the license has not been modified in any significant manner; trust in the social sense when parties are well-defined.
6. Asset protection: mechanisms to embed information in the assets in order to detect misuse and identify infringing parties.

Rights information. Rights in the broad sense, as identified in DRM, are actions or a class of actions (or activities) that a subject may perform on an asset (Contentguard 2001; Iannella 2002; Park and Sandhu 2004). Therefore, rights enable users to access assets in a particular mode, such as reading or writing (Park et al. 2004). Rosenblatt et al. (2002) identify render rights, transport rights, and derivative rights as the three comprehensive categories, with rights within the categories (playing, extracting, etc.) varying according to content and applications.

In addition to the three types of rights mentioned by Rosenblatt et al., issuance rights (the rights to issue grants of other rights) and delegation rights (the rights to delegate a grant to another party) are examples of essential rights over rights (Chong 2005). We collectively call these rights administrative to distinguish them from the above core rights. This general functional categorisation of rights fits any digital rights domain.

- **Render rights** refer to the representation of content on some output medium (playing, viewing, printing, etc.).
- **Transport rights** are the rights to move or copy content from one place to another. The differences between copying, moving, and loaning have to do with which users have access to the content at any given time. In copying, user 1 gives a copy of content to user 2, and both have access to the content simultaneously. In moving, user 1 gives up access once content is given to user 2. In loaning, user 1 gives up access to the content temporarily until user 2 gives the rights back.
- **Derivative rights** refer to the manipulation of content to create derivative work: using pieces of content out of their context (extracting), changing the content (editing), or inserting the content into another product (embedding).
- **Administrative rights** are rights over rights (e.g., the right to delegate a certain set of rights to others).

The above categories can be applied to the geospatial domain. For example, an extract feature right is a derivative right, and a regrant right (allowing licensees to grant licenses to sublicensees) is an administrative right. The categories act as units of functional aggregation of rights.

Rights constraints. Constraints on rights are attributes that are attached to each of the above fundamental rights. Attributes include considerations, extents, and types of users (Rosenblatt et al. 2002). Geospatial assets also require spatial constraints.

- **Considerations** are anything a user has to give in exchange for a certain right. An obvious consideration could be money, or it might be a certain form of agreement between the publisher and the user. For example, a publisher might allow someone to use content in return for a copyright notice in the produced work.
- **Extents** specify how long, how many times, or in what places the rights apply.
- **Types of users** can have different rights or right attributes. For example, educational institutions constitute a particular category of users.

Unique identification. Unique identification of licensed content is an integral part of any DRM license. The digital object identifier (DOI) is a standard for online content identification and linking. It is based on URI and URN (uniform resource name) and governed by the International DOI Foundation. A DOI assigned to a digital asset, be it data or service, uniquely identifies that asset. Using regular URLs as a means of identifying digital content is not convenient, because they point to a specific location of an asset or files. If the location of the asset changes, the URLs become invalid. A DOI points to a master table called the DOI directory where each DOI record is assigned a URL that leads to the asset. URL changes are always synchronised with the DOI directory.

Geospatial-data providers can use DOIs to uniquely identify each asset covered by a GeoDRM license.

Rights metadata. In an open distributed network like the Web, users need to be able to search and discover assets based on different types of generalised information.

For example, users can search music based on genre, date of creation, and so on. Although this specific element is not mentioned in the DRM literature, we believe it is an important aspect that is specific to geospatial data. In the geospatial realm, users can search for data through metadata catalogues based on date of creation, specific keywords, and so forth. The role of metadata is to provide information about collections of assets to enable search and discovery. OGC has defined the Catalogue Service for the Web (CSW) to enable clients to search and discover data based on well-defined metadata elements. These elements are defined in the ISO 19115 specification. We recommend that the ISO 19115 metadata standard and its implementation in the CSW be expanded to support searches based on geospatial-data rights metadata. A GeoDRM CSW profile is an important subject that has yet to be considered by the OGC GeoDRM working group. We recommend the following categories for rights metadata:

- **Licensee metadata** specifies the types of users who can have licenses and access rights to an asset (e.g., academic institutions, commercial users).
- **Licensor metadata** identifies the authority that controls the data (as addressed in the ISO 19115 standard).
- **Rights metadata** specifies types of rights and constraints.

Trust information. Trust has both a technical meaning and a social meaning. From a technical perspective, a trusted system is a system that can be trusted to honour the rights, conditions, and fees specified for a digital work. Systems that play, read, or provide access to digital works on a network can be subject to trust. Different implementations of trusted systems have different requirements for security. In the most secure approaches, all of the hardware and software on the platform is certified to honour digital rights. Other approaches focus on the use of so-called secure envelopes or containers, emphasising transmission and storage of information.

From a social perspective, GeoDRM has significant impact on trust between parties participating in geospatial information sharing (Harvey 2003; Harvey et al. 2004)—between government agencies, between the public and private sectors, or between commercial entities. Trust can affect a GeoDRM-enabled SDI on many fronts, including the following:

- Accessing a geospatial service after signing a digital license specifying a level-of-service agreement and terms of use (e.g., "do I trust this service enough to build an emergency application?")
- A government entity licensing a valuable dataset to a user for noncommercial purposes (trust is increased since all participants and rules are well-defined)

A minimum level of information is required in a GeoDRM license to facilitate trust between parties involved in an agreement. Trust would be context sensitive: for example, in certain situations the quality of a dataset could be the major basis of trust, while in other cases the party from which the data originates is the basis of trust.

Asset protection. Digital content can be encrypted and then decrypted by private keys embedded in the license. The encrypted content cannot be used unless a valid license with the corresponding keys is made available (Rosenblatt et al. 2002).

Digital watermarking is an adaptation of the commonly used and well-known paper watermarks to the digital world. Watermarking makes it possible to embed some essential metadata fragments within the content instead of having metadata alongside the content (Rosenblatt et al. 2002). Digital watermarking provides methods and technologies for hiding information (for example, a number or text) in digital media, such as images, video, or audio. The embedding takes place by manipulating the actual digital content. That means that the information is not embedded in the frame around the data. The modifications of the media have to be imperceptible.

Research on geospatial-content watermarking is still in its infancy. However, in digital imagery it is a more mature area than in vector formats, even with multiple commercial vendors offering watermarking protection of imagery. Two-dimensional vector and point datasets have received less attention from the research community (Lopez 2002).

TECHNOLOGIES FOR REPRESENTATION OF RIGHTS

Many technologies for rights representation exist, from metadata standards (for example, the Dublin Core [DC 2005]) to Right Expression Languages (RELs). Also, publishing requirements for industry standard metadata (PRISM) (PR 2005) provide a good base for representing rights information on the metadata level. This representation, however, is meant to be machine interpretable. Even with XML encodings the purpose remains documenting metadata, which does not provide essential facilities for representing digital licenses like security models and digital license structures.

RELs provide a means of managing the expression of contractual-agreement rights in a machine-interpretable format for all sorts of digital assets. They aim to provide a vocabulary and semantics for the expression of terms and conditions and to enable machine-based processing of digital contracts (Guth et al. 2003). RELs have also been defined as a type of policy specification language where the focus of the language is on expressing and transferring rights from one party to another in an interoperable format (LaMacchia 2002).

The concept of RELs originated when the Digital Property Rights Language (DPRL), a LISP 1-based language, was developed by Mark Stefik of Xerox's Palo Alto Research Center (a patent application was filed in 1994, and the patent was granted in 1998). Stefik created DPRL as a machine-readable language that could be used to define access rules and procedures, for use with the trusted PC. Stefik based DPRL 2.0 on XML, because XML is extensible and was interoperable with other emerging standards. From DPRL emerged ODRL and XrML. ISO-REL and MPEG-REL were then developed on the basis of XrML (figure 7).

To be used in the geospatial domain, RELs would naturally need to be extended to accommodate requirements for specifying digital licenses on geospatial assets (for example, without extension, a REL doesn't have the ability to specify a license with spatial extents having x,y dimensions). In our research we have adopted ODRL. Being open source and readily available makes ODRL ideal for research purposes. (The process of extending the ODRL 1.1 standard to accommodate spatial requirements and spatial data types is beyond the scope of this article.)

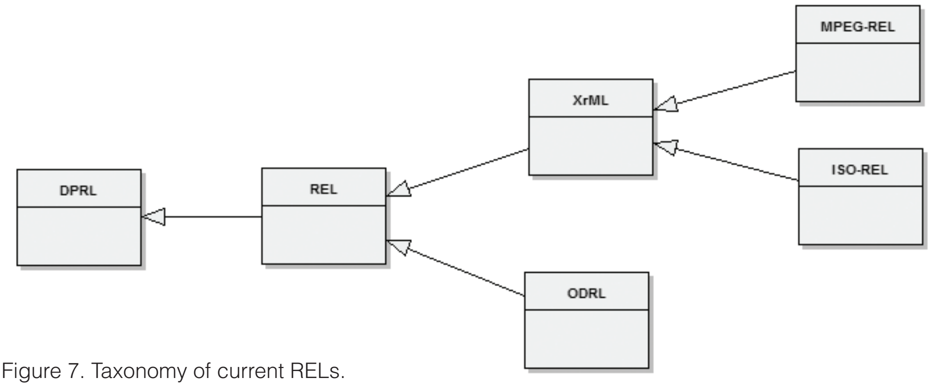

Figure 7. Taxonomy of current RELs.

THE ROAD AHEAD

We offer a concise agenda for future research on GeoDRM which leverages the findings of our research. The items below constitute a high-level research agenda for a full-fledged SDI capable of managing IPR of producers and users of geospatial datasets. More sophisticated business models can be developed for new and innovative products and services across the SDI.

- GeoDRM has legal and technological aspects. A GeoDRM policy is country specific and must use legal and technical means to achieve its goals. Further research into both aspects must define the country-specific guidelines for developing integrated legal and technical measures of implementing GeoDRM.
- Studies are necessary to evaluate how digital licensing and other GeoDRM technologies will affect business models of geoinformation (GI) organisations.
- Harvey (2003) and Harvey et al. (2004) stress the importance of trust as an element in defining geospatial data sharing patterns. Understanding trust and its effects is important in building GeoDRM systems. For example, does higher trust entail lower security measures on GeoDRM systems? And how can the concept of trust leverage GeoDRM's ability to unambiguously define liabilities and duties of parties involved in GI data sharing?
- Each of the elements within the GeoDRM information model needs further study to identify the implementation details in a myriad of situations in the geospatial domain.
- Since digital licenses contain information about geospatial assets (e.g., boundaries), could these licenses be used as service access tickets? For example, do we need GetFeature permissions for WFS, or is sending the license (which constitutes an implicit GetFeature request) sufficient? Users could send licenses to services, which would then release datasets accordingly. Licenses would also be used to enforce the rights on the client machine.
- Current metadata standards and the OGC CSW service need to be extended to accommodate the rights metadata needed for GeoDRM (as discussed above). Also, a GeoDRM product catalogue needs to be established to enable expression of generalised licensing frameworks for negotiating licenses.

- The semantics of digital licensing need to be studied. We believe that ontologies and rules (Web Ontology Language [OWL], Semantic Web Rule Language [SWRL]) will provide reasoning capabilities for resolving conflicts in combining various geospatial assets with heterogeneous licenses.
- Research and development of the GeoDRM architecture is an essential step in establishing a GeoDRM-enabled SDI, facilitating the testing of the technology and of the theoretical concepts.

CONCLUSIONS

An obstacle to the adoption of Web-based geospatial technologies is the intrinsic loss of control over IPR by vendors and providers. Many IPR challenges are apparent in Web-based environments due to the high accessibility afforded by these technologies. The need for adequate IPR management is essential for Web technologies to receive wider acceptance in the geospatial community. Moreover, providers are motivated by more sophisticated geospatial business models that could be developed over the Web and that are hindered by loss of control over IPR downstream in the value chain.

GeoDRM provides an essential legal framework for SDIs, allowing stakeholders to maintain IPR without hampering accessibility to services. In this article, we have proposed a GeoDRM architecture that can integrate with Web services in general and OGC Web services in particular, along with a technology-neutral GeoDRM information model identifying the essential information elements for GeoDRM infrastructures. Further GeoDRM research must leverage current DRM standards. Both the proposed GeoDRM architecture and the information model capitalise on current research in digital licensing infrastructures. The above agenda provides direction for future research on GeoDRM.

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