Geospatial Digital Rights Management with focus on Digital Licensing of GML datasets

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By

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Abstract

In today's networked environments, the geospatial value chain is growing more complex. New web services and digital media are opening a window of new web based business models. In this environment, geospatial data can be easily shared copied, used and reused as well as redistributed across the geospatial value chain. That limits the ability of providers to control the flow of their intellectual property downstream in the value chain. Same forces affecting geospatial data industries have previously influenced other digital media industries for which digital rights management emerged as means for providers to control the flow of their intellectual property. Geospatial digital rights management (GeoDRM) is a novel topic that lacks formal literature. This makes the definition and understanding of the basic components of GeoDRM an essential part of this research.

A major component of the GeoDRM is digital licenses. Thus, the fundamental research problem is the expression of rights on geospatial assets to enable the construction of digital geospatial licenses, specifically the problem of licensing vector datasets manifested in GML format is tackled as a step towards an integrated licensing framework for digital geospatial assets.

This research was conducted on three main phases. Phase I was dedicated to understanding the field of GeoDRM. We have realized that GeoDRM consists of both legal and technology aspects. Any GeoDRM implementation is a combination of legal and technical measures acting together to form a GeoDRM policy for the organization. Separation between the two aspects in implementations would result in inefficient GeoDRM policies that either relies too much on technology where it's not needed or would rely too much on legal measures where it's not effective. We then defined GeoDRM by means of a modified GeoDRM spectrum to reflect the different components of GeoDRM. In phase II of the research we have conducted the technical analysis of digital rights management technology and have derived the GeoDRM reference architecture. We have also proposed a GeoDRM information model. At the end of this phase we provided a model for the Geospatial License (GeoLicense) and a general requirements list to extend a rights expression language to construct licenses for GML data assets.

In the third and last phase of this research, we have provided an implementation of the Geolicense by extending a digital rights language (ODRL) to accommodate the Geolicnese requirements for the GML data assets. The approach is based on using the GML vocabulary within the rights language data dictionary to construct spatial data types and provide spatial extension of the ODRL language. We then provided a proof of concept by building licenses of three scenarios based on Ordnance survey licenses. Due to the lack of GeoDRM technology implementations, we have developed the schema and proof of concept using the XML development IDE Altova XMLSpy.

A major conclusion of this research is that rights expression languages are a powerful tool for expression contractual agreements. We have adopted it to the geospatial domain on GML data assets. Further research needs to be done to better assess the technology and to deepen the understanding of the GeoDRM over all requirements.

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Mohamed Bishr
March 3rd, 2006

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Glossary of Terms

Asset

An Asset is defined in the Webster dictionary as “an item of value owned”. In the realm of Service Oriented Architecture (SOA), an organization can own the rights to a service rather than digital content. In this sense an asset refers to both digital content and services.

Digital License

A computer interpretable contractual agreement that acts as a unit of aggregation of rights granted from a licensor to a licensee over an asset.

DOI

Digital Object Identifier is a standard for online content identification and linking based on URI and URN governed by the International DOI Foundation.

DRM

Digital Rights Management, a technology that facilitates the persistent authorized use of digitally delivered assets.

GeoDRM

Geospatial digital rights management. It can be defined as a set of technologies and legal frameworks that are fit to a certain organizational need, forming a GeoDRM policy for enabling rights managed geospatial networks (e.g. SDIs) where all rights over geospatial assets are specified by the licensors. Any licensee would be “trusted” to honor the licensors conditions within and beyond the network’s trusted environment.

GeoLicense

A digital license describing a contractual agreement between parties over a geospatial asset.

GML

Geography Markup Language is an XML vocabulary for encoding geographic information in order to be stored and transported over the web. Developed by the Open Geospatial Consortium OGC. And is currently being certified as ISO 19136.

IPR

Are statuary rights that cover any work that conforms to the requirements of a minimum amount of creativity, and provide a means by which the creator can control the copying and distribution of his work and gain income and recognition for it.

ISO REL 21000-5

A Rights expression language derived from XrML.

License

A formal contractual agreement setting out the terms and conditions under which a licensee may receive and use data, information and other material supplied to him/her by a licensor, who may not necessarily be the owner.

REL

Rights Expression Language, A from of policy specification language where the focus of the language is on expressing and transferring rights from one party to another in a machine interpretable format.

ODRL

Open Digital Rights Language, provides vocabulary and data dictionary for the expression of digital contractual agreements.

PKI

Are sets of servers, software, protocols and application programs used to manage the private keys and public keys of a group of users (Keys cryptography mechanisms used to encrypt or to digitally sign digital resources to ensure authenticity of the resources).

XML

Extensible markup language developed by the W3C and is a derivative of SGML. It allows for building structured documents enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.

XML Schema or XSD

A language for specifying the models that describe the structure of information within XML documents.

XrML

Extensible Rights Markup Language, a REL developed by contentGuard and is widely adopted in the DRM domain.

WFS

Web Feature Service, It can serve vector datasets to users over the web. It connects at the backend with Vector datasets in a myriad of formats. These vector datasets are then converted into GML (Geography Mark up Language) and transported to users over the web.

WMS

Web Map Service which is developed by OGC, is the production of spatially referenced data dynamically from geographic information over the Web. The map itself is an actual portrayal of geographic information presented as a digital image file for display on a computer. WMS maps are in picture formats such as PNG, GIF or JPEG, or as Scalable Vector Graphics SVGWeb Map Server

1. Introduction, Problem Statement and Research Methodology

1.1. Introduction and Motivation

In late 1980s and early 1990s content providers, technology firms, government organizations and policymakers were confronting the effects of ubiquitous computing networks on the availability and dissemination of digital content many of which happens to be copyrighted. Ease of dissemination of digital geospatial content started posing threats to intellectual property rights (IPR). As technology pushes various industries into the digital frontier many types of content are becoming solely available in digital formats, Geospatial data is no exception to this technology force. A Map that is copyright protected and sold in paper sheets is now available in digital format for a variety of users and devices, from car navigation systems, handhelds, and mobile phones all the way to datasets running under the skin of corporate applications and enabling business related geospatial functions. Digital geospatial datasets moving across computer networks can be easily copied transformed or incorporated into new value add products and services. Geospatial data producers and owners are faced with the challenge of controlling the dissemination of their IPR on digital geospatial content downstream in the geospatial value chain.

In (Onsrud, *et al.* 1998) Harlan Onsrud argues that such environment is not only driven by the desire for monetary gain. Rather, the recognition due to authors and moral rights associated with the use of spatial data are important issues to encourage the establishment of the public geo-information commons. In a geospatial web-services environment with ubiquitous dissemination of digital datasets, parties engaging in data sharing activities (e.g. producers and consumers) need the recognition same way as book authors need to be cited when there books are used in other works. Such environment gives more incentives to producers to publish or otherwise make Geospatial data easily accessible and available.

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 broader one. DRM solutions originally evolved in the media industry where digital delivery of content is quickly gaining popularity and where IPR infringement is a serious and direct threat to the current business models. The narrower definition of DRM focuses on persistent protection of digital content. DRM provides an automated system that will consistently and rigorously enforce agreements made among users, providers, and distributors. It allows the distributor of data to control how data is used, and by whom, in accordance with rules and agreements in compliance with a given business model and/or IPR schemas. While the broader definition of DRM encompasses everything that can be done to define, manage, and track rights to digital content. In addition to persistent protection, this definition includes the following elements(Rosenblatt, and Dykstra, 2003):

- Business rights (a/k/a contract rights): an item of content can have rights associated with it by contract, such as an author's rights to a magazine article or a musician's rights to a song recording. Such rights are often very complex and have financial terms attached to them that depend on the content's use (e.g. royalties).
- Access tracking: DRM solutions in the broader sense can be capable of tracking access to and usage operations on content. Information about usage is often inherently valuable to content providers, even if they do not charge for the usage of content.

Recently higher awareness of the IPR problems within the geospatial domain gave rise to a discussion of the challenges surrounding the management and dissemination of IPR. In (Onsrud *et al.*, 2004) DRM is briefly addressed as a suggested solution for the management of geospatial IPR. Other researchers (Vowles, and Mckee, 2005) proposed a Geospatial DRM vision for public geospatial data libraries and geospatial marketplaces. Recently OGC (Open Geospaqtial Consortium) formed a GeoDRM working group (OGC GeoDRM-WG) with the mission statement of adopting the work done in the area of data ownership and digital rights management to the geospatial community. The Group addresses the lack of geospatial digital rights management (GeoDRM) capability as a barrier to wider adoption of Web based geospatial technologies. At this stage by using the term GeoDRM we pertain to the General definition stemming from DRM. GeoDRM is the means for management of IPR in the digital web-based geospatial data sharing environment. Later in this thesis we develop a more formal definition of GeoDRM.

1.2. Context of the Research Problem

In web environments, services are employed to deliver geosaptial datasets to users. Figure 1-1 below illustrates an example of web services which is the WFS (OGC 2002-WFS) The WFS is the Web Feature Service. It can serve datasets to users over the web. It connects at the backend with Vector datasets in a myriad of formats. WFSs can be cascaded which means a WFS can use another WFS as a datasource. The vector datasets on the WFS backend are converted into Geography Markup Language (OGC 2005-GML) and served to users. GML is an XML-based language for encoding geographic information in order to be stored and transported over the Internet. GML was Developed by the OGC and is currently being standardized as ISO-19136, GML defines both the geometry and properties of objects that comprise geographic information.

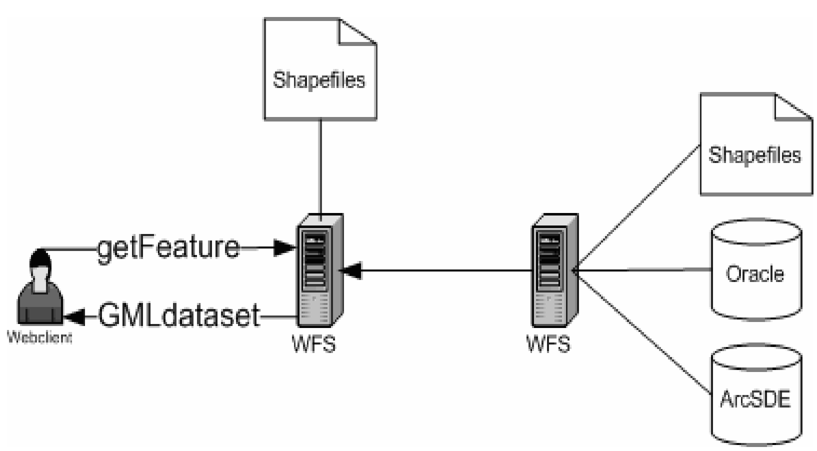

Figure 1-1 Geospatial Web services configurations

Geospatial data poses unusual problems for the protection of IPR. Among these problems are the variety of formats in which geospatial data is delivered and the variety of services such as analysis web-services or OGC web-services mentioned above.

The two challenges are a major drive behind DRM for the Geospatial domain

- In The DRM domain there is variability in data formats (multimedia formats), however content is always disseminated, as discreet units for example a book is not part of a whole, a book in that sense is a standalone discreet unit. While in figure 1-1 a GML dataset sent to a user and is covering a district is part of a larger whole that is the entire city.
- Also in figure 1-1 a typical use of geospatial data also involves cascading information from multiple data sets and integrating them to create a new data set like, entering gray areas of mixed and sometimes conflicting IPR. It is therefore necessary to have detailed terms and conditions for the many aspects of access, use, and dissemination of IPR to protect the providers' interests in web based geospatial data sharing.

At the heart of DRM is digital licensing. Digital licensing is a translation of a contractual agreement over IPR between interested parties by which one party gives certain rights over an asset to another party. Digital licenses are basically computer interpretable units of aggregation of those rights. Computer interpretable digital licenses mean that management and enforcement of these licenses can be automated. In DRM Rights Expression Languages (RELs) are developed to express digital licenses and provide the semantics and vocabulary for formulating complex contractual agreements examples of RELs are ODRL (ODRL 2002), and the XrML (XrML 2004) derived languages MPEG-REL and ISO21000-5.

1.3. Problem Statement

Geospatial data can be distributed in analogue form (e.g., hardcopy maps) or they can be distributed in digital form through web services as part of a SDI or business networks. The later poses serious implications on the ability of geospatial content providers to manage their IPR downstream in the value chain and hence hamper social and economic progress in developed and developing countries alike. Data providers want to be able to offer their digital geospatial data in a way that guarantees the protection, recognition and honoring of their intellectual property against any use that does not conform to their specific contractual agreements. GeoDRM as a novel topic lack formal definitions and literature. This research aims as a step towards a full-fledged GeoDRM framework by identifying GeoDRM architecture and the general GeoDRM components. A major component of the GeoDRM is digital licenses. Thus, the fundamental research problem is the expression of rights on geospatial assets to enable the construction of digital geospatial licenses, specifically the problem of licensing vector datasets manifested in GML format needs to be resolved as a step towards an integrated licensing framework for all digital geospatial assets.

1.4. Main Objective

- To identify an appropriate method to describe contractual agreements for licensing of geospatial digital content via a rights expression language and develop an extension to an existing licensing standard as a proof of concept

1.4.1. Sub Objectives

1. Define the elements of GeoDRM framework.
2. To develop a high-level architecture for GeoDRM digital licensing.
3. Define a General GeoDRM Information model.

1.4.2. Research questions

1. What is DRM and how is it different from seemingly similar fields like access control?
2. How are Geospatial Intellectual property rights currently being disseminated?
3. Why GeoDRM is needed in today's geospatial data sharing environments?
4. how can we define GeoDRM more formally, What is the Formal definition and scope of GeoDRM?
5. How digital licensing of assets is managed on web environments?
6. What are the components of the GeoDRM architecture?
7. How can we develop a GeoDRM information model and what are the components of the GeoDRM information model?
8. What are the general requirements of geospatial rights expression on GML datasets?
9. How do we accommodate the above requirements in existing Rights expression languages?

1.5. Research Design and Flow

In this research we have conducted the approach depicted in Figure 1-2. The research was divided into three phases. In the following sections each of the research phases are highlighted with a more detailed explanation.

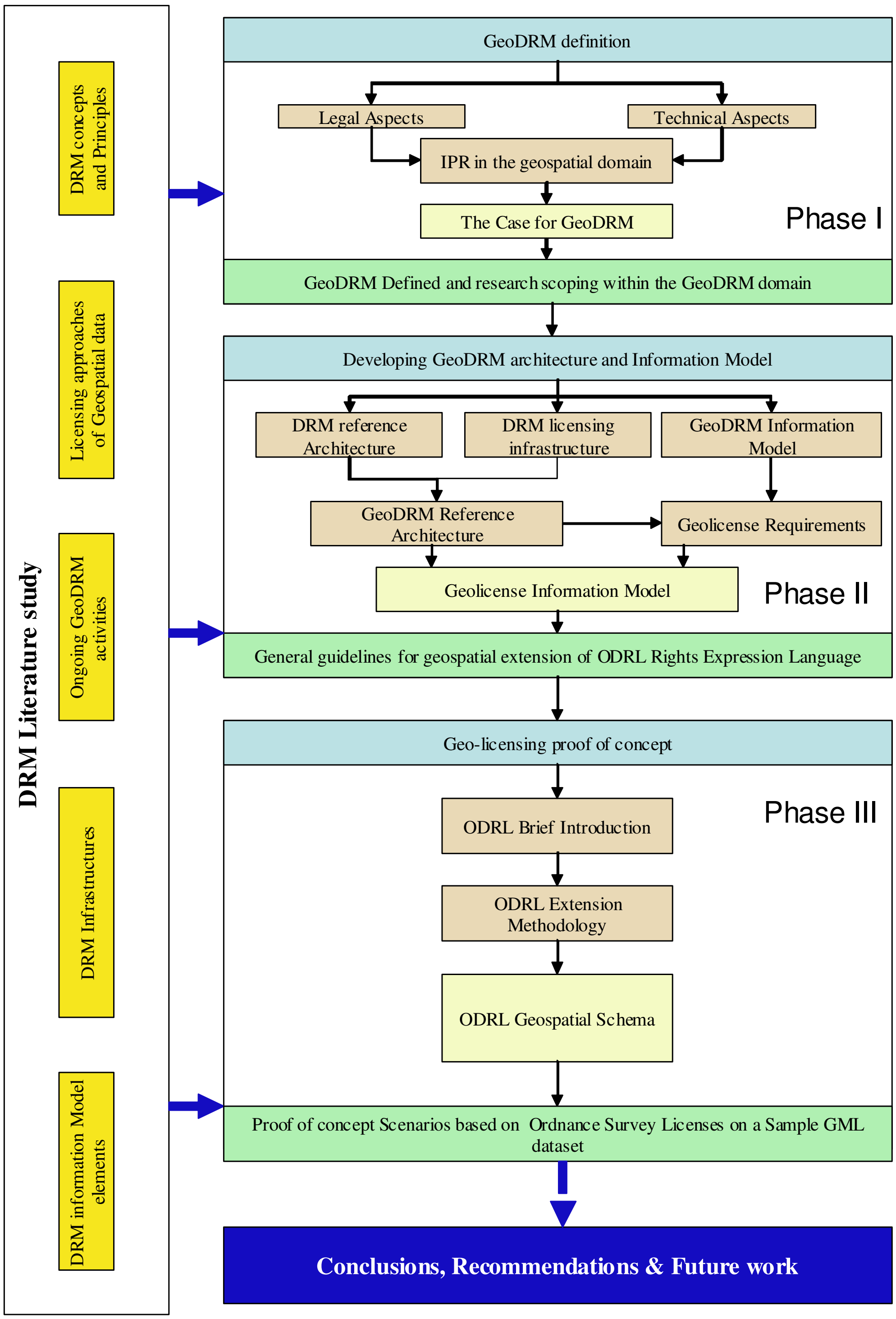

Figure 1-2 Research design and Flow

1.5.1. Phase I GeoDRM Definition

In the first phase we approach the GeoDRM problem with the intention to set the foundation for understanding the GeoDRM field and to position this research within the larger picture of GeoDRM. To achieve this we study current DRM definitions and define the relation between DRM and another common field which is access control. Stemming from this part we adopt a wider definition of DRM. We then study the relationship between IPR law and contract law (licensing) and reflect the finding on GeoDRM. This assists in establishing the case for GeoDRM through examining GeoDRM related activity in some organization where relevant activity is taking place. At the end of this phase we define GeoDRM and set the scope of this research within the larger picture of GeoDRM.

The main output of this phase is:

- Identifying and understanding the two major aspects of a GeoDRM policy (legal aspects, and technical aspects).
- A formal definition of GeoDRM to guide the development of this research.

1.5.2. Phase II: GeoDRM architecture & Information Model

In this phase we study the technical aspects of GeoDRM. We approach the research problem from a DRM digital licensing perspective. We address the DRM reference architecture and modern DRM licensing infrastructure to derive the GeoDRM reference architecture that is capable of managing digital licensing in web environments. Utilizing literature study of the elements of information within DRM digital licensing infrastructures we derive the GeoDRM information model where we focus on rights information as an essential element for our research. By feeding the information derived from the GeoDRM reference architecture and the information model along with additional study elements we identify the requirements for the geospatial rights expression. As a final stage we derive the geospatial license (geolicense) model.

The main output of this phase is:

- The GeoDRM reference architecture
- The GeoDRM information model
- The Geolicense requirements and model.

1.5.3. Phase III: Geolicensing Proof of Concept

In phase III we address the extension of Open Digital Rights Language to enable the expression of the geolicenses on GML data. We illustrate the methodology followed to derive geospatial capabilities to ODRL to build the “GeoREL” this methodology can then be applied to any other REL to achieve similar functionality. In the same phase, we provide a proof of concept for the developed GeoREL schema by implementing licenses on a sample GML dataset. The licensing scenarios are derived from Ordnance survey Print/Copy shop license. Due to lack of GeoDRM technology implementation at the time of writing this thesis, we have used Altova XMLspy IDE (Integrated software development environment) to validate the syntax and type checking of the developed schema as well as to validate the licenses against the developed GeoREL schema.

The main output of this phase is:

- GeoREL XML schema

- Sample licensing on a sample GML dataset depicting the proof of concept.

1.6. Research Contribution

- Proposed high level architecture and reference information model and Geolicense model.
- Proposed Extension of Rights Expression Language (REL) to support GML datasets.
- Proof of concept implementation for the Extended REL on a sample GML dataset using a licensing scenario based on Ordnance Survey Print/Copy shop license.

2. Definition of GeoDRM

2.1. Introduction

Geospatial DRM (GeoDRM) is a novel topic with very few supporting literature, hence at the start of this research there was a lack of understanding of the scope and purpose of GeoDRM. An initial step for this research was to understand the basic components of DRM and reflect that on the geospatial domain to define GeoDRM. This would then enable us to scope this research within the bigger picture of GeoDRM.

DRM and consequently GeoDRM deal with Intellectual property rights (IPR) thus; it is important to consider that services provided by DRM technologies are governed by legal, cultural, and social constraints pertaining to IPR laws and regulations. Therefore, it is important to develop a basic understanding of these aspects and their effects on DRM. In DRM Rights can be viewed as acts which users are entitled to over certain assets. This spans all acts that access, modify, merge, or duplicate any content also; it includes terms of use for online services and other assets. DRM consists of both technical and legal frameworks, the understanding of both is essential to build DRM policies that meet requirements of a specific situation. GeoDRM would also consist of a technical and a policy framework.

In section 2.2, we define access control from a critical point of view as opposed to DRM, which puts DRM in a more clear perspective. The goal of 2.5 is to establish the definition of DRM, that would later contribute to a wider understanding of the domian. In section 2.4, we discuss the legal aspects surrounding DRM in general and the implications of these aspects on GeoDRM in particular. In section 2.5 we address the case for GeoDRM by examining current approaches within the vision for a Geospatial marketplace, the INSPIRE initiative, Ordnance Survey MasterMap and Open Geospatial Consortium. Section 2.6 combines the conclusions derived from the previous sections into a common understanding of GeoDRM and then the chapter is concluded in 2.7 by scoping this research within the larger picture of GeoDRM.

2.2. Digital Rights Management (Byond Access Control)

In today’s network-connected, highly dynamic, and distributed computing environments, digital information is likely to be used and stored at various locations and therefore has to be protected. In highly distributed systems where identity of subjects is usually unknown and the location at which the digital content is used is not constant, authorization cannot be determined from an authorization database. Instead, authorization is granted to trusted parties using public-private key infrastructure. Public Key Infrastructures (PKI) are sets of servers, software, protocols and application programs used to manage the private keys and public keys of a group of users (Keys are cryptography mechanisms used to encrypt or to digitally sign digital resources to ensure authenticity of the resources). A user uses his private key to encrypt his content, and distributes his public key to others who are interested in decrypting the content. Users are generally able to create and update their own key pairs, and a Certificate Authority is used to sign new Public Key's (Sandhu, and Samarati, 1994). In recent years, research in authorizations has been pursued under the name of trust management. Both traditional access controls and trust management deal with the protection of digital resources within the trusted environment of a resource provider (Park, and Sandhu, 2004). None of these systems deals with protection of resources on the client machine outside the trusted environment of the provider. (Schneck, 1999) introduced a new perspective on access control problems considering requirement for persistent access control, in the sense that protection of any digital resource occurs wherever this resource exits (e.g. on a server or when content is moved to a client environment). (Park *et al.*, 2004) showed the difficulty of achieving this on a large-scale distributed environment and proposes usage control as an extension to access control. Modern DRM in many aspects is a reflection of the usage control. In the next section, we address the definition of DRM.

2.3. The Definition of DRM

Recently the term Digital Rights Management (DRM) emerged focusing on controlling Intellectual property rights of already disseminated digital content (i.e. how rights holders have agreed there content should be used) .Many definitions of DRM are offered by researchers. (Liu, Sheppard, 2003) defines DRM as a system to protect high-value digital assets and control the distribution and usage of those digital assets. (Rosenblatt, Trippe, and Mooney, 2002) has a more general definition where he defines DRM as a system where its ultimate goal is to make mass copying and distributions difficult. In this definition, Rosenblatt refers to illegal mass copying, use, reuse and distribution of digital assets that is becoming more common place in the networked environments, and the role of DRM is to make mass copying unlikely to appear.

Another widely accepted definition of Digital Rights Management is *"The ultimate goal of a distributed DRM system is for content authors to be able to project policies governing their assets use into remote environments with confidence that those policies will be respected by the remote nodes"(Lamacchia, 2002).* Digital content providers need to be able to project their policies on assets to be enforceable regardless of the location of the assets. This last requirement highlights the need to express rights persistently and couple them with the digital resources as they move on the network.

The above definitions rather stem from content background (i.e. as opposed to services) because current DRM solutions have been largely driven by commercial media industries and are mainly focused on intellectual property rights (IPR) protection of content, (Park *et al.*, 2004) and (Rosenblatt *et al.*, 2002). In this research, we adopt the following definition which focuses more on technologies to manage rights. (Contentguard, 2001), (Park *et al.*, 2004) define DRM as technology that facilitates the persistent authorized use of digitally delivered assets. This definition extends Digital Rights Management to include all rights, from intellectual property rights to all usage rights and access rights for services and digital resources in the broadest sense all within a distributed network environment.

Since DRM aspires for the management of rights over digital asset. In this research, we adopt a certain definition of the term Asset. An asset is defined in the Webster dictionary as "an item of value owned". In the realm of Service Oriented Architecture (SOA), an organization can own the rights to a service rather than digital content. Hence, services may also earn the attribute of being of value. In this sense, we use the term asset to refer to both digital content and services.

By a service, we mean a web service that are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web. Web services perform functions, which can be anything from simple requests to complicated business processes, once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service. Geospatial web services are web services that have geospatial functionality like data analysis for example. Since web services are exposed over the web, it is important to ensure security of the web services. Prominent DRM technologies like ISO REL, XrML and ODRL are being further exploited by the technology developers; XrML is being used to control rights of use of Web Services(Contentguard, 2001). For example, a geospatial web service may provide the user with the ability to do generalization of his datasets. For this user to be able to use the service he must prove he has the essential rights to execute the service. RELs can be used to describe the user rights over this service in an access ticket form. The user then has to supply the license to the service to be granted authorization to use the service and do the generalization.

It is important to note that the definition adopted above closely relates DRM with access control from a technical perspective at a certain level of abstraction. This observation was also confirmed by (Lamacchia, 2002) and (Park *et al.*, 2004) who argue that there is a significant unity between DRM and the access control fields. We can assert here that DRM can be used to manage all rights on digital assets. From above these rights include two distinct categories (Lamacchia, 2002), (Park *et al.*, 2004),(Contentguard, 2001):

- Intellectual property rights (Licenses) where licenses are defined as formal agreements setting out the terms and conditions under which a licensee may receive and/or use assets, information and other material supplied to him/her by a licensor, who may not necessarily be the owner.
- Service usage rights (includes access rights)

However, despite the technical similarity at some levels between DRM and Access control they remain fundamentally different. The fact that DRM stems from IPR background has more profound effects on the understanding of DRM, We assert that the major difference between DRM and access control lies in the fact that DRM has to be supported by a legal framework. While organizations might have access control policies, these policies are not legally binding. It is simply means to state which parties can access which resources. In DRM however, policies are legal agreements between parties the first place.

An integral component of DRM systems is digital licenses; a DRM digital license (Figure 2-1) has the same legal meaning as a legal contractual agreement and acts as its digital equivalent to aggregate the terms and conditions of the agreement in a computer interpretable format. It is of utmost importance to recognize the fact that DRM is simply means of managing and reflecting actual legal agreements onto the digital environment.

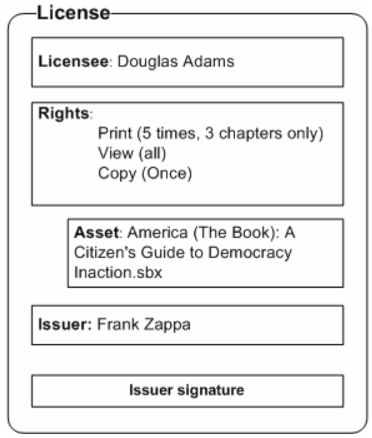

Figure2-1 A Simple view of a DRM license

In the next section, we address the DRM policy framework to understand the policy aspects surrounding DRM.

2.4. The DRM Policy Framework

As we established in the previous section, DRM consists of a policy and a technical framework. (Duncan, *et al.* 2004) identify the following general DRM stages in the formation of DRM policies. These stages are not mandatory. Not all the stages have to be fulfilled but the stages are the logical steps to the realization of a full-fledged DRM policy.

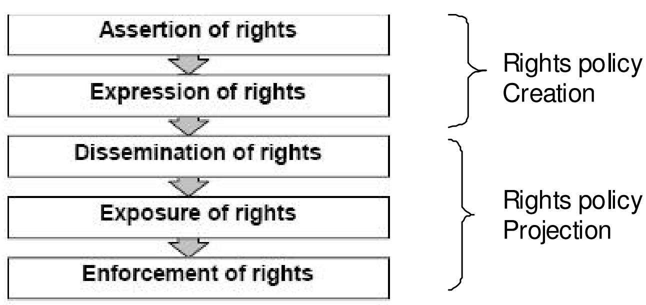

Figure 2-2 Stages of Realization of DRM

Rights Policy Creation:

a. **Assertion of Rights:** is provided by a legal framework in which people and organizations can assert their rights in a form that is defendable under law. Several license models are emerging, (e.g. creative commons and open source licenses which are licensing schemas that belong to the "Copyleft" movement, which intends to reduce the restrictions imposed by IPR law on the usage of assets).

b. **Expression of Rights:** has traditionally involved only a copyright statement in a human-readable form. While this is still important it is also essential to take into account machine-to-machine (m2m) communication when considering the expression of rights for DRM, hence legal licensing terminology needs to be simplified and streamlined.

Rights Policy Projection

a. **Dissemination of Rights:** ensures that whenever an asset is described, its rights are also described. This is the first stage in enforcing the DRM Policy. It requires that when asset hubs, catalogues, or portals gather metadata they also gather rights metadata hence rights holders are confident that assets are always coupled with rights metadata.

b. **Exposure of Rights:** is the stage at which users view rights information associated with assets. This will often be when searching for assets. If there are differences between the permitted uses for different assets then these should be easily apparent without detailed scrutiny of license conditions. The semantics of terms used in a license must be unambiguous and well understood by subjects using the assets so that understanding and projecting rights information is effective and accurate.

c. **Enforcement of Rights:** includes protective measures to ensure that rights are not infringed and steps to be taken when infringements are detected as well as legislation for the protection of the technical measures taken.

The subsequent two sections we will introduce two major aspects which demonstrate the policy requirements that should be taken into consideration when designing a DRM system. The first aspect is the EU directives which are considered a high set of policies that are meant to guide and support DRM policy makers by providing legal protection for DRM implementations and legal protection for database rights. The second aspect is the relation between IPR law and Contractual agreements which reflects on DRM

2.4.1. EU directives on DRM and Database copyrights

Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonization of certain aspects of copyright and related rights in the information society has provided legal ground for the digital management of rights (DRM) by providing anti-circumvention law for DRM technology. This directive is equivalent to the US digital millennium copyright act.

Another directive would have profound effect on the dissemination of Digital Geospatial Datasets is DIRECTIVE 96/9/EC which is pioneered by the EU and is leading the change around the world. DIRECTIVE 96/9/EC Database Directive established an entirely new intellectual property right, called a "sui generis" right (from the Latin "of its own kind"). This right takes its place next to other IPR rights of trademark, copyright, and patent. Under the Directive, database makers can, for a period of 15 years from the completion of the database, prevent unauthorized extraction and reutilization of the contents of the database.

A database which will benefit from the sui generis right is described as "a collection of independent works, data, or materials arranged in a systematic or methodical way and individually accessible by electronic or other means." Databases may include any type of information, such as text, sound, images, numbers, facts, or raw data. It is for this reason that commentators have also referred to the Directive as the "Multimedia Directive." Electronic and print databases are covered. Many geospatial datasets are provided as relational databases and this new IPR provides new strength for protection of rights on geospatial databases.

Both directives 96/9/EC and 2001/29/EC provide solid grounding for DRM as the means for management of IPR and ultimately for GeoDRM as means of Geospatial IPR management via two layers of legal frameworks:

- The first directive provides legal protection against circumvention of DRM technology (e.g. decoupling an asset from its digital license), hence DRM implementations are protected against illegal attempts to isolate the manage assets from the rights managed environment.
- In addition, the later directive extends IPR law to be explicit on databases in general.

The first point above is an essential measure to make DRM solutions feasible for the management of IPR, by imposing legal measure to prevent any tampering with the solutions and covers both policy projection aspects and policy enforcement. Consequently, this directive covers any geospatial solution for management of geospatial IPR within the GeoDRM framework. The second point provides IPR law coverage for all databases including geospatial databases. This in turn indicates a challenge facing GeoDRM policy makers as to how to strike a balance between statutory rights and contractual rights which we will illustrate the implications of in the next section by defining the formal relation between statutory rights and Contractual rights (licensing).

2.4.2. Statutory Rights Vs Licence Rights in the Geospatial Domain

Intellectual Property Rights (IPR) traditionally covers four main rights (Figure 2-3): copyright, patent, design, and trademarks. Other rights have recently emerged such as the Database rights (Sui genreis rights, as discussed above).

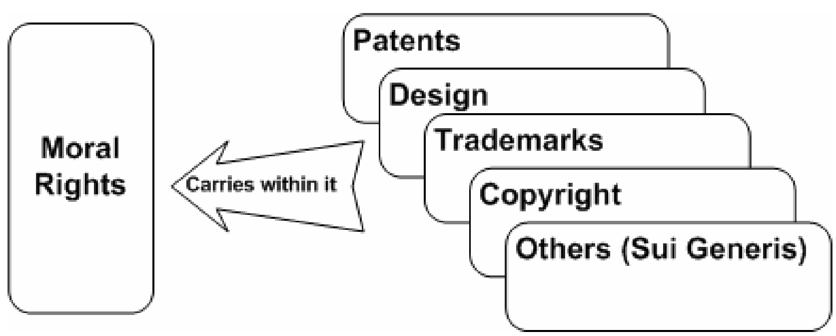

Figure 2-3 Bundle of IPR law rights

Generally, IPR are statuary rights that cover any work that conforms to the requirements of a minimum amount of creativity. It provides means by which the creator can control the copying and distribution of his work and gain income and recognition for it. This recognition constitutes the component of the implicit moral rights within the IPR law. This in turn assures creators that even when their creations are lawfully used it has to be used appropriately and in a manner, that shows respect to them. Copyright is binding to a buyer of a book automatically by committing the transaction of buying a book. Licensing on the other hand, requires a contractual agreement which both parties establish together. Current rights management systems don't directly map to current copyright laws, the reasons being that the user's Intellectual property rights are a result of the reconciliation of two different and sometimes conflicting rulings (Chong, 2005):

- Statutory rights granted by the IPR law in each country (e.g. copyright, Sui generis).

- Rights permitted by the rights holder (e.g. author or digital library) to a user through licensing.

The IPR laws and in particular the copyright law depended heavily on the notion of "copying" as the major source of infringement of IPR. Copying in the digital world however, is not a good predictor of intent to infringe. Copying of digital works is sometimes necessary for normal use of those works. In place of the right to copy, the right to control public distribution and uses of the copyrighted work through digital licensing might gradually replace ordinary copyright laws (Miller, and Feigenbaum, 2002). In summary, the following two observations are important:

- Licenses do not relinquish the IPR granted by the law unless explicitly stated in the license terms
- The relationship between licensing and IPR law needs to be addressed while setting licensing policies for DRM. This will enable us to avoid potential conflicts between statutory rights and licensed rights.

The dissemination of IPR on geospatial content is mainly done via licensing. It is noted that researchers acknowledge that licensing of geographic data and works has come of age mainly because of the limited protection afforded by copyright and other intellectual property doctrines in the digital environment (Onsrud *et al.*, 2004). According to the reasons, licensing has become commonplace can be summarized as:

- The realization that many geographic data, as opposed to geographic creative works, are difficult to protect through copyright alone
- A shift away from supplying distinct datasets to providing access to databases which means each distinct part downloaded has potentially different license agreement.
- Increased concern over potential liability and a desire to limit liability through explicit license systems.
- The rise of shared cost and data maintenance partnerships means that various parties can assume IPR ownership on various aspects of the same dataset.
- Developments in network technology and digital geospatial datasets have been accompanied by increased use of licensing as an alternative to the outright sale of the data and data products a trend that is similar with other content types.

Licensing of geospatial assets means a transaction or arrangement (usually a contract, including maybe an exchange of value) in which the acquiring party (i.e. the licensee) obtains information with restrictions on the licensee's rights to use or transfer the information. Examples of such restrictions include:

- Limits on the persons or entities (such as other agencies or the public) to whom the information may be disclosed.
- Limits on the purposes for which the information may be used.
- Limits on the duration of the license.
- Limits on ability of a licensee to delegate licenses to other parties, and provisions regarding ownership and use of products developed through the use of the licensed information.

In Figure 2-4, we conclude the above section by illustrating the relation between IPR Law and Contract law and the abstract role of GeoDRM as follows:

- Intellectual property rights can be managed in two distinct ways, IPR law and licensing. The shifting towards licensing is synonymous with the advent of digital datasets and online dissemination of the geospatial assets.
- Licensing can provide wider (copyleft) or narrower freedoms than is granted by the IPR law. If GeoDRM policies are not crafted properly, conflicts may arise between statutory laws such as copyright and Sui genereis rights. Hence, the GeoDRM policy framework must consider these issues.

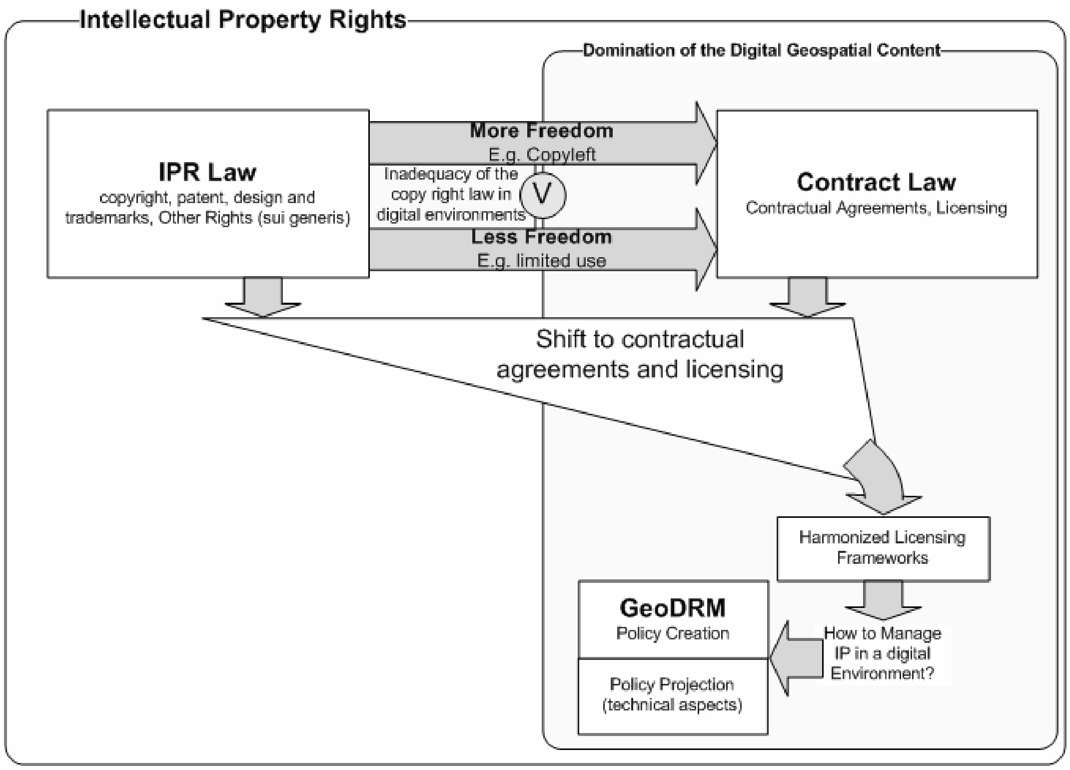

Figure 2-4 relationship between IPR law and Contract law with respect to GeoDRM

- The shift to contract law requires harmonized licensing frameworks. This would enable building less complex GeoDRM service infrastructures to meet the needs of varying geospatial stakeholders.

In this section, we have learned that management if IPR in the digital environment using DRM and subsequently GeoDRM needs two layers of supporting legal frameworks. First, there is the legal protection of the GeoDRM framework against any infringements or breaches of the technical measures applied. Second are the legal contractual agreements that are represented in digital format and used to disseminate IPR on geospatial assets.

2.5. The Case For GeoDRM

Both developed and developing countries are putting their geospatial data holdings online. However, one of the major obstacles for ubiquitous geospatial web services is that data providers lack technology to maintain the intellectual property on their assets. Hence GeoDRM is always addressed from the point of view of new business models suited for the online geospatial environments. A specific GeoDRM configuration depends on four major aspects (Vowles *et al.*, 2005):

- The business of the organization, for example the motivations of commercial public-sector, and academic organizations to make their geodata available.
- The types of data and media formats such as physical, electronic, text, graphic, vector, raster, observations etc..
- The content distribution channels, size of content, network bandwidth, types of end user devices.
- The types and granularity of intellectual property rights to be protected and the contractual obligations for its use. For example license to reuse parts, limited distribution, sensitive/classified.

The complexity of each aspect of the above makes the task of defining GeoDRM as one technology in a clear cut definition not a practical matter since different organizations and business models would lead to a different understanding of the role and components of GeoDRM. In this section we briefly address three different examples to deduce conclusions relevant to the purpose of definition GeoDRM. These conclusions are then fed into section 2.6 to define GeoDRM and place this research within the wider picture of GeoDRM.

2.5.1. The Geospatial market place

As a summery of the vision from the research conducted by the Committee on Licensing Geographic Data and Services, National Research Council of the US (Onsrud *et al.*, 2004). A National Marketplace for Geographic Information would provide an online environment where any licensor (rights holder), no matter how small could:

- Efficiently post its offerings in a searchable form using a menu of standard licenses and metadata reporting.
- Would-be purchasers could search through thousands of offerings to find the geographic data that meet their technical and license condition needs.
- In the simplest implementation of the marketplace, purchasers would obtain the data directly from the vendor after “clicking through” to contact its server.
- Minimal investment could provide a combined license and metadata creation capability for sellers and search capability for consumers within a short time.
- In more advanced implementations, the licensor might define detailed digital licenses or sale conditions tied to defined pricing formulas and participate in automated financial transactions and downloading of products.
- Digital licenses can then be used to track the usage of the vendors IPR as well as for automated enforcement of the license terms.
- Buyers would be able to accomplish efficient comparison-shopping and buy or license desired geographic data within minutes of finding it. Licensors accounts could be automatically credited with funds from product sales, and sellers would be able to alter their geographic data offerings, descriptions, license conditions, and pricing formulas at any time.

Same model can accommodate geospatial web services for processing or mapping as geospatial assets (e.g. WFS) where a license to access and use a certain service is granted by the licensor and a licensee can submit the license to any service which would validate the license and enforce the embedded set of rights. (Onsrud *et al.*, 2004) briefly discusses DRM as means of management of rights in the online geospatial marketplace. In this vision, GeoDRM is a central part of the marketplace providing IPR management capabilities.

2.5.2. Providing Geospatial Content Online

Ordnance Survey (OS) provides many digital Vector as well as Raster data. MasterMap is digital map designed by Ordnance Survey for use in advanced GI applications. Based on the National Grid, it includes topographic information on every landscape feature. From buildings, roads, phone boxes, postboxes, landmarks. MasterMap presents this comprehensive, large scale, advanced information as themes in a series of layers, each layer carrying millions of features. Each feature in OS MasterMap has its own unique identifier (TOID) which is a 16 digit unique number. This allows easy data association and greater accuracy in coupling datasets. Data can be searched online based on many criteria which include area, Layer, license period, and number of users.

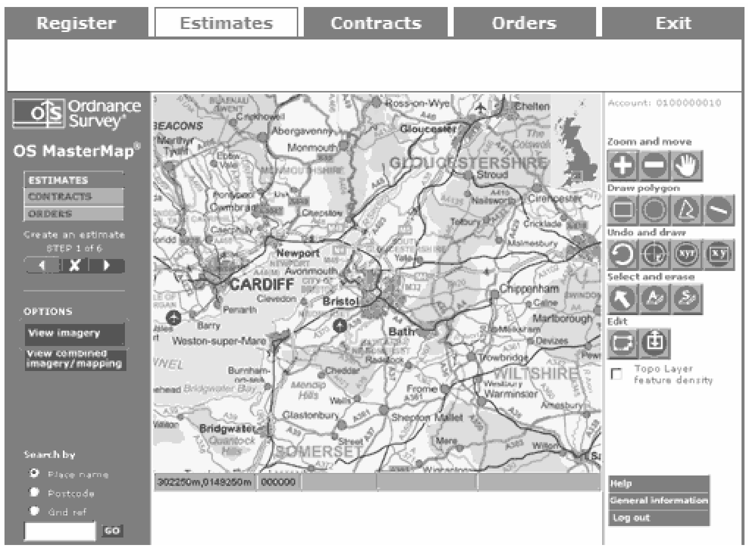

Figure 2-5 Ordnance Survey MasterMap Selecting Map area to be licensed by the tool box to the right

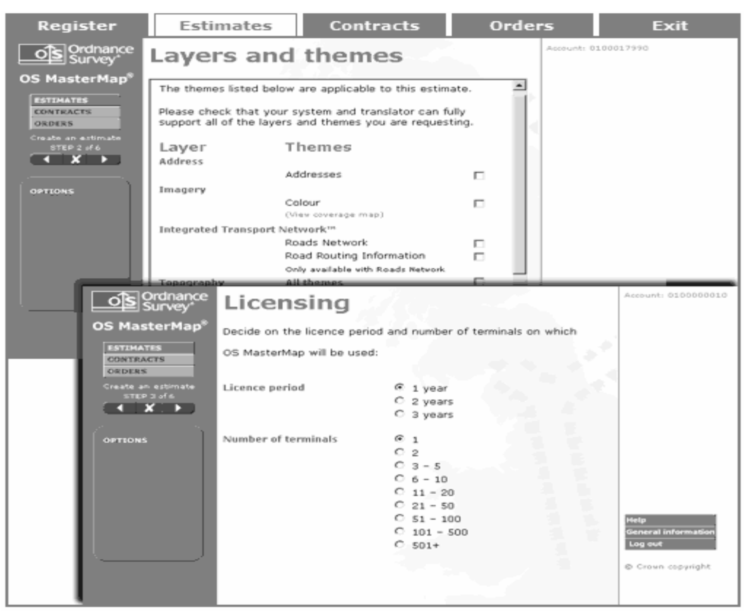

Figure 2-6 OS selecting licensing Terms and licensed layers or themes

Figures 2-5 and 2-6 illustrates the process of purchasing MasterMap data which is highly automated, the web site allows users to register and provide their personal information and the intended use of the data.

Users then proceed to define layers, themes, and area of interest as well as additional licensing terms (e.g. duration of license, number of users). Once the selection process is done, the user can place an order for the dataset or save the session and come back to it later with payment information to place an order. The user prior to placing an order must accept a series of click-through licenses. Once the order is processed and the delivery medium of the data is selected (CD, DVD, FTP download) the user either waits for the delivery of the dataset is case of CD and DVD or can wait 1 day before receiving notification that his dataset is ready for download from the FTP.

OS currently provides click-through license mechanisms (where users click acceptance of licensing terms on a computer screen). Click through online licenses enables access to a wide range of official information launched by the UK's HMSO (Her Majesty's Stationary Office which is the custodian of Crown Copyright, which covers most central government information. Shrink-Wrap is the US equivalent of this license. Courts have upheld these licenses and ruled them binding(Onsrud *et al.*, 2004). OS as a Member of OGC (Open Geospatial Consortium) is a major player in the GeoDRM working group (2.5.4). OS intends to establish a technical framework to accommodate OS licensing needs based on the GeoDRM framework. Where automated license management would provide OS the ability to track, protect and manage the dissemination of IPR downstream in the value chain.

2.5.3. European INSPIRE initiative and IPR licensing

The INSPIRE initiative aims at establishing the European SDI to deliver users integrated spatial information and services. The first phase of INSPIRE is to focus on environmental policies and then extend to other sectors such as agriculture, transport and energy (Inspire, 2005). The initiative provides basic geospatial information in 31 initial themes on a European level. These themes constitute mostly foundation data provided by the governments of the member states. Initial actions of INSPIRE include among others, establishing harmonized licensing frameworks for data access and sharing and to establish a clearinghouse network including services for discovery, query, view, download and trading of geospatial data. Ultimately, INSPIRE aims at establishing a geospatial marketplace, it is expected that that a thriving market for value add services will develop on top of public sector spatial data.

INSPIRE initiative defines a license as a formal agreement setting out the terms and conditions under which a licensee may receive and use data, information and other material supplied to him/her by a licensor, who may not necessarily be the owner. The initiative identifies the owner of the IP to be the center of gravity. Ownership may involve more than one set of rights like moral, authorship, commercial, etc(Inspire, 2004).

The four dimensions of IPR dissemination in INSPIRE (Figure 2-7) are driven by market models (no cost, cost recovery, etc…) which lead to a policy framework in which access, permitted usage, charging rates, royalties, obligations and responsibilities of the parties must be well defined.

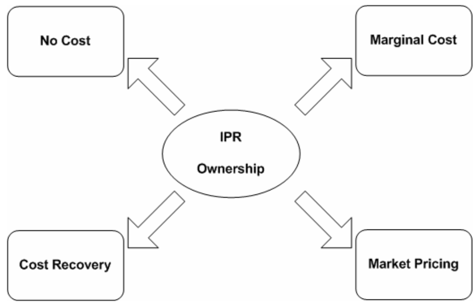

Figure 2-7 the control of IPR

It is essential, therefore, that the policy and legislation takes this into account to ensure that owners and rights holders have flexibility to decide or influence the terms and conditions of such information sharing and trading(Inspire, 2002). The initiative defined a general policy which we summarize below to exemplify regional policies:

- Clearly define the spatial datasets to which public access is limited and the reasons for such limitation.
- Impose an obligation to supply information for any purpose subject to basic licensing arrangements. Type of use directly relates to which type of licensing arrangement was needed. Types of use include personal, commercial use and re-use
- Simplify licensing arrangements for personal use. Propose to use a click-through license notice of terms and conditions that is deemed to be accepted.
- Ensure that the scope of copyright applies uniformly throughout the EU. This is especially important in the context of maps and map products.
- Metadata must be made available and shall include information about rights of use of spatial data.

The inspire initiative in general stresses on the importance of clear and harmonized licensing frameworks for the 31 data themes initially covered by the first proposal. The stress on these harmonized licensing frameworks is important to be able to achieve feasible click-through licensing mechanisms that are valid across the EU member states. In other parts of the proposal where value added products are mentioned licensing takes more commercial approaches that are similar to those exhibited in 2.5.1 and 2.5.2 by OS.

2.5.4. GeoDRM in the Open Geospatial Consortium

By mid 2004, the OGC (Open Geospatial Consortium) established a GeoDRM working group with the mission of coordinating and maturing the development and validation of work being done on digital rights management for the geospatial community. The objectives set for the working group are:

- Enable business models for web-based geospatial services by identifying or developing a trusted infrastructure for purchasing and protecting rights to digital content.
- Guide the development of OGC specifications and best practices recommendations to permit the exploitation of mainstream DRM approaches, technologies, and standards wherever possible.
- Test, verify, and mature as necessary the technologies required for GeoDRM including electronic commerce and information security.
- Develop specifications for GeoDRM that build on the OGC technical baseline.

Currently a draft GeoDRM reference model is being crafted by the working group. The draft has not been released at the time of writing this thesis. During the technical meeting in Bonn, a click through licensing mechanism was illustrated for the WMS. This was an initial step for a test bed for GeoDRM technologies. (OGC 2002-WMS). Web Map Service which is developed by OGC is the production of spatially referenced maps dynamically from geographic information over the Web. The map itself is an actual portrayal of geographic information presented as a digital image file for display on a computer. WMS maps are in picture formats such as PNG, GIF, or JPEG, or as Scalable Vector Graphics SVG. The explicit statement of the need to capitalize on and exploit mainstream DRM approaches, technologies, and standards is among the guiding principals of the working group.

2.6. GeoDRM Defined

In the previous sections, we have examined DRM on controlling usage and dissemination of digital assets according to some well defined digital license agreements between the involved parties. These digital licenses map to legally binding agreements that constitute the legal framework of DRM or the policy creation aspects. Assets in as previously discussed can pertain to services or contents. In addition, we have established that GeoDRM would have policy aspects pertaining in the first place to the contractual agreements as well as technical aspects. We have also concluded that GeoDRM is highly dependant on the factors provided in section 2.5 and many different GeoDRM implementations will exist depending on these factors hence it's not practical to define GeoDRM as one set of technologies or a single policy.

With this view in mind GeoDRM can be defined as a set of technologies and legal frameworks that are fit to a certain organizational need, forming a GeoDRM policy for enabling rights managed geospatial networks (e.g. SDIs) where all rights over geospatial assets are specified by the licensors. Any licensee would be "trusted" to honor the licensors conditions within and beyond the network's trusted environment. Trust in this definition 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 then mapped to digital equivalents must support GeoDRM. This makes a GeoDRM license a legal tender that must be respected.

(Vowles *et al.*, 2005) provides an interesting perspective on GeoDRM as a spectrum of technologies. Figure 2-8 provides an elaborated on version of this DRM spectrum in which we have added the knowledge acquired from this chapter to deepen the understanding of GeoDRM. From the figure above, we can see that:

- As business models change according to organizational needs, so do the GeoDRM schemas used to disseminate IPR, for example INSPIRE opts for click-through licensing for most of the data themes covered by the initiative, while OS already has click-through licensing and are opting for Digital licensing and tracking to their assets.
- The legal framework of GeoDRM is inseparable from the technical framework and together they from 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 organization.

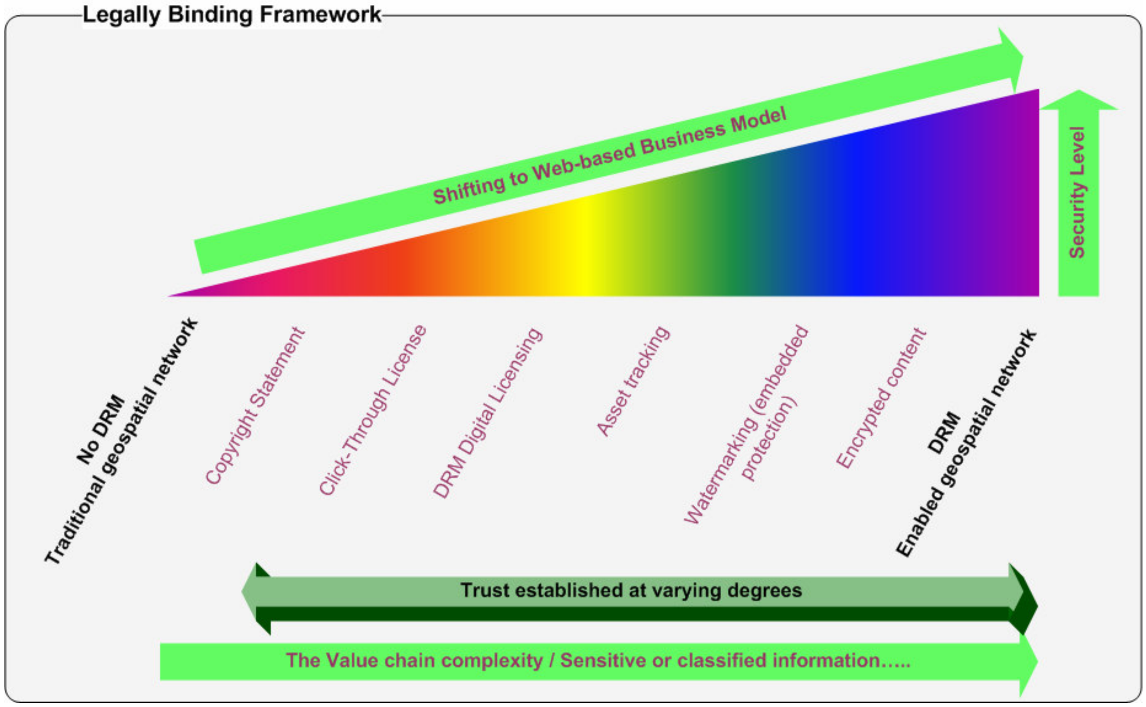

Figure 2-8 GeoDRM framework components.

- Trust is an essential component of GeoDRM and is an explicit reflection of the Moral aspects of IPR that were discussed earlier this chapter. In the geospatial information sharing 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). Harvey argues that trust from that perspective is important for geospatial data sharing and as geospatial information and maps replacing experiential knowledge (e.g. I trust that this map is accurate and decision are taking upon that trust) establishing trust in geospatial data sharing environments is essential. GeoDRM in that sense by assuring parties of the identities of each other's and the preservation of their IPR increases trust in the data-sharing environment.

This research spans on one aspect of the GeoDRM spectrum which is DRM Digital licensing for the geospatial domain (GeoDRM Digital Licensing) and particularly for Vector datasets manifested in GML.

2.7. Conclusions

DRM technology in its broadest sense is concerned with management of all rights on digital assets where an asset as discussed pertains to content and services. Although the focus of this research is on the technical aspects of GeoDRM Digital licensing, we have demonstrated that GeoDRM legal framework are inseparable from the GeoDRM technical framework as this technical/legal setting forms the GeoDRM policy of an organization or a certain group of stakeholders. We have argued that there exist a clear distinction between IPR laws as statuary rights and licenses as contractual agreements between parties and that licensing is the dominant mood of geospatial IPR dissemination. Many researchers argue that current copyright laws will need to change to better suit the digital realm, since copying is not anymore a sign of the intention to infringe on IPR by users(Mitchell, 2004). In section 2.5 the case of GeoDRM was presented with examples from Geospatial market place vision, INSPIRE, OS, and OGC.

We concluded by a formal definition of GeoDRM and finally by defining the area of interest of this research within the GeoDRM spectrum which is GeoDRM digital licensing. Within digital licensing this research focus on the rights expression of the licenses and particularly licensing of Vector datasets manifested through web feature servers in GML.

In the next chapter we will introduce the proposed GeoDRM architecture as a solution for GeoDRM digital licensing and a GeoDRM Information model to guide the development of an approach to the expression of rights on geospatial assets.

3. GeoDRM Architecture and Information Model

3.1. Introduction

In section 3.2 we first examine the context within which digital licensing occurs by examining the DRM infrastructure. We first illustrate the DRM reference architecture and explain its components then we examine a modern digital licensing infrastructure that focuses on digital licensing of assets as discussed in this work. The findings of these two aspects guide the development of GeoDRM architecture (see 3.3). Three usage scenarios of the architecture are then illustrated regarding the sequence of interactions on the system. The GeoDRM architecture is a high-level architecture, which illustrates the major components of GeoDRM and assists in understanding of the information model developed later.

By combining the knowledge acquired from the scenarios and by examining the essential elements of DRM digital licensing we derive the General GeoDRM information model (see 3.4) and elaborate on the components of the model in subsequent sections. Later we address the geolicense information model (see 3.4.3) which illustrates the essential spatial extension to the digital licensing model based on the general requirements derived earlier. This chapter is then concluded in section 3.5.

3.2. The DRM Infrastructure

In this section, we provide an overview of the GeoDRM reference architecture. To achieve this goal we first provide a brief description of the DRM services by examining the DRM reference architecture and the digital licensing infrastructure that are common amongst most DRM systems. This will enable us to realize the main services that should be enabled by GeoDRM systems. From a digital licensing perspective DRM systems and GeoDRM are not fundamentally different we also follow an approach on adopting current digital licensing and DRM technology into the geospatial domain to build on already established concepts.

3.2.1. General DRM Architecture

(Rosenblatt *et al.*, 2002) introduced a general high-level architecture that is widely adopted in the DRM domain as shown in Figure 3-1. This architecture depicts 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, grants licenses, the license server generates the digital license, and the publisher associates 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(Rosenblatt *et al.*, 2002). The controller acquires 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 finally executes the license terms.

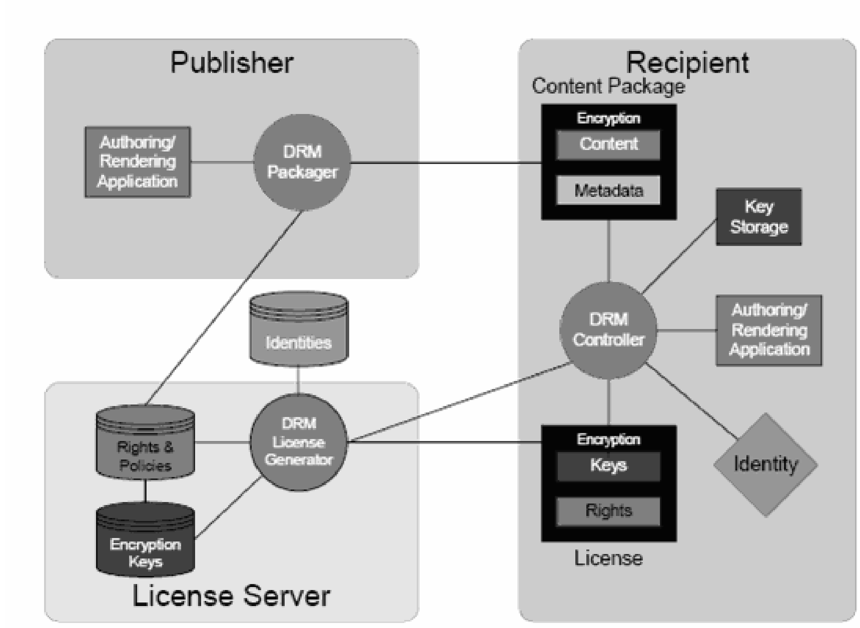

Figure 3-1 DRM Reference architecture (Rosenblatt *et al.*, 2002)

The above architecture does not provide insight into the process of the management for digital licensing. In addition, similar to many DRM implementations it is developed from a content background. However, we can deduce three major components from this architecture to guide the development of the GeoDRM architecture:

1. A Provider Server. This issues the assets being licensed. In chapter 2 while defining DRM, we concluded on the nature of Assets which could be content or services. This understanding of assets shows the shortcomings of the DRM reference architecture which perceives assets only as content.
2. A client component which is an essential component to manage DRM related activities (e.g. enforcement of licenses, negotiation with a license server).
3. A license server. Which is shown in simple form and is based on licensing of discreet unites of content. However more recent developments in digital licensing infrastructures have a more service oriented approach and stress the importance of interacting with users to define licensing terms and conditions for both providers and users (Thompson, and Jena, 2005). Such a licensing infrastructure is illustrated in section 3.2.2.

From the above architecture, we understand the basic skeleton of DRM architectures. We then look into licensing infrastructure for the licensing of services and content and address how this licensing infrastructure fits the context of our research context of licensing non-discreet assets as addressed in section 1.2.

3.2.2. General DRM licensing Services

Digital licensing infrastructure as presented here captures the larger picture of services that are necessary for DRM systems to function. As shown in Figure 3-2 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 to terms and conditions of use (Thompson *et al.*, 2005):

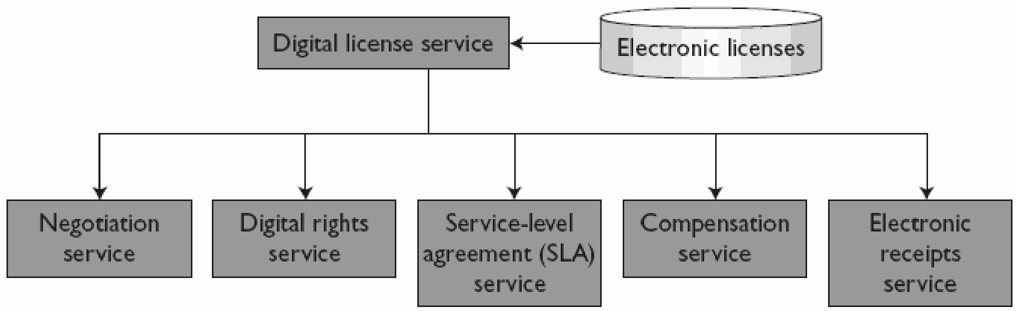

Figure 3-2 Digital Licensing Infrastructure (Thompson *et al.*, 2005)

Digital license service manages licensing by providing the following specialized services:

1. DRM packaging Service packages a geospatial dataset file or stream with its license as well as encrypt the stream of files if requested at runtime before dispatching the package as a Geospatial Object.
2. Service-Level Agreement service defines an optional section of a license. For certain service types (i.e. mission critical or emergency services) some licenses would contain penalties and service level parameters. A vendor might agree to pay for underperformance below some quantified level of service. Or maybe acknowledge legal liabilities.
3. 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 standalone applications the service requestor purchases. *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.
4. 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.
5. License Negotiation Service provides offers and counteroffers between vendors and consumers until they reach an agreement (translated into a digital license) are reached. 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.
6. Digital License Service is the administrative hub of the infrastructure through which the workflow between the other infrastructure services is managed. Assets being licensed register there desired offers within the “electronic licenses” database thus; users can negotiate and issue licenses on the desired assets.

In Figure 3-3, we illustrate the usage of the digital licensing infrastructure through the sequence of interactions:

1. The client request a license offer from the digital license service
2. The digital license service delegates the request to the negotiation service
3. The negotiation service determines the identity of the user which is included in the offer request, and accordingly issues a callback function to the digital license service instructing it to generate a custom offer to the user which include custom SLA and compensation

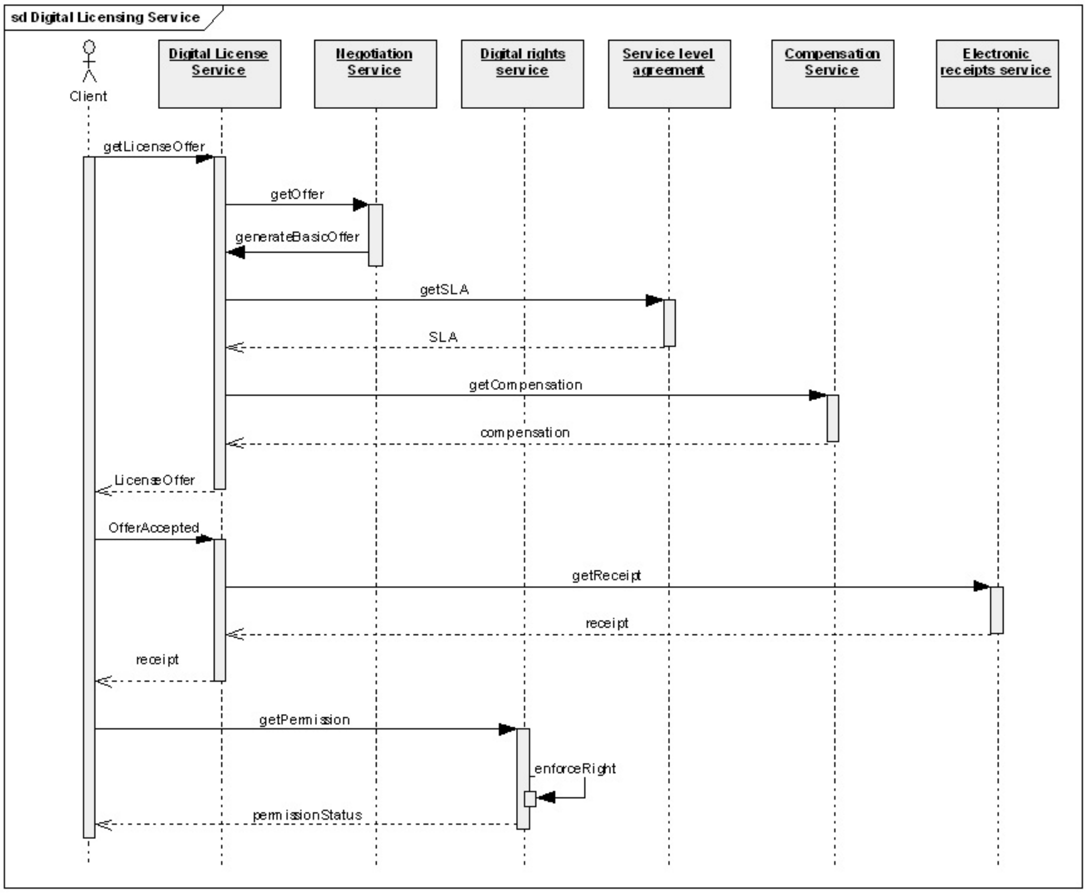

Figure 3-3 Sequence diagram illustrating interactions between the Digital licensing infrastructure services

4. The callback function from the negotiation service includes parameter values that the digital license service uses to construct the offer
5. The digital license service requests a service level agreement from the SLA service.
6. The digital license service request the compensation value from the compensation service which then credits the user to the account of the author.
7. The offer is assembled at the digital license service and forwarded to the client
8. The client may refuse the offer and request another offer which enhances some of the offering parameters. Based on this information the negotiation service may issue a callback to the digital license service instructing to generate another offer with modified parameters
9. Once the offer is accepted the digital license service request a receipt from the electronic receipt service, which is then forwarded to the client
10. Every time the client requests to use asset, the client issues a getPermission request to the digital rights service to check if the request right is within the bounds of the accepted license.
11. The digital rights service enforces the right and responds to the client with permission status.

This digital licensing infrastructure is designed to manage licensing of content and services in a variety of settings. We envision that GeoDRM would require such complex licensing capability. In this section, we have addressed the DRM reference architecture and analyzed its basic components. We then reviewed a service based digital licensing infrastructure and how the services interact to fulfill user requests. Earlier this section we established that GeoDRM architecture for digital licensing should not be fundamentally different from that of other DRM. Since the entities managed, are digital licenses. While geospatial licenses would be different and would require a certain level of different management, we assume that from a high abstraction level the differences between both architectures are minimal.

3.3. GeoDRM Architecture

Figure 3-4 shows a formal UML component diagram of the high level architecture. The GeoDRM service is composed of all the services defined in the general DRM reference architecture and digital licensing services discussed in 3.2.1 and 3.2.2, which combines the capabilities of modern digital licensing infrastructure with client side management of licenses.

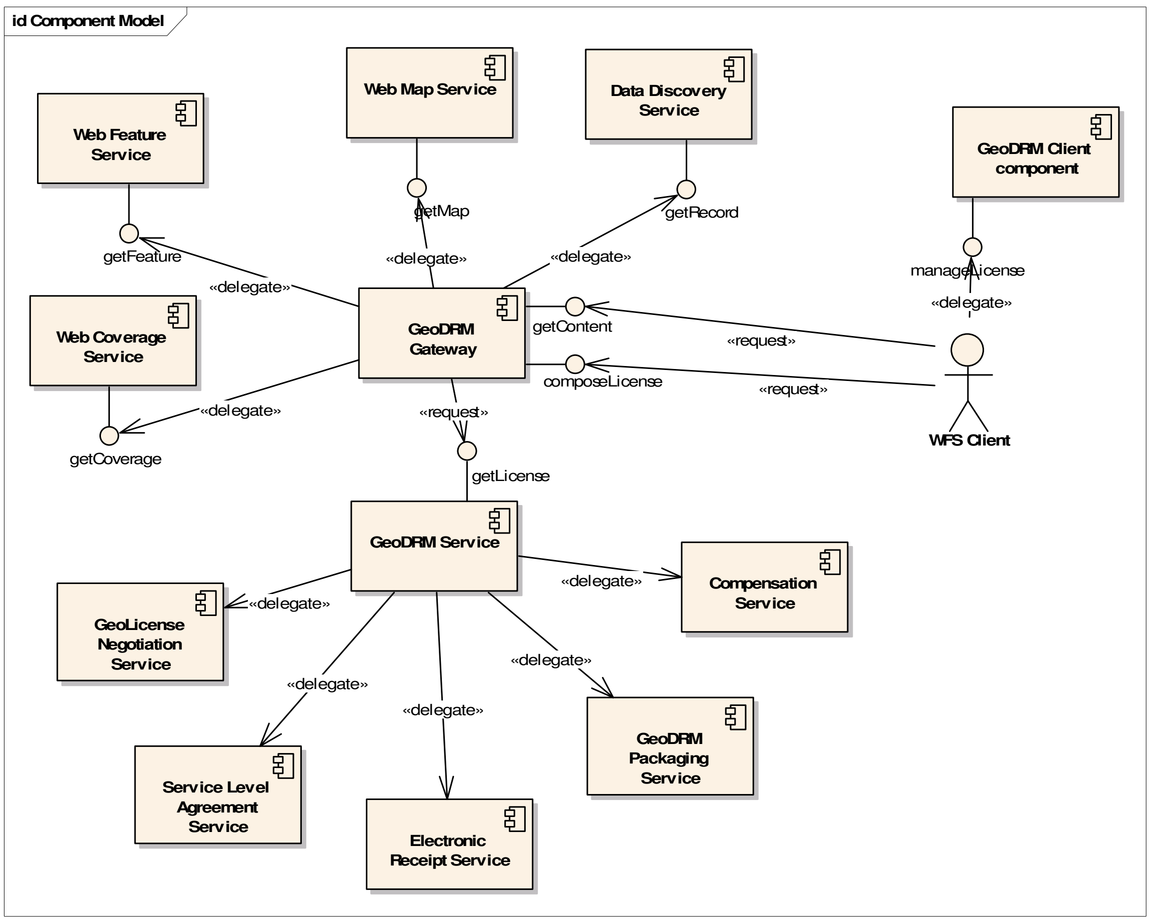

Figure 3-4 GeoDRM architecture by means of a UML component diagram

The GeoDRM service can be located in the publisher's environment but it could also be a third party trusted license provider service. The client component has the responsibility of managing licensing related client side interactions with the GeoDRM service. The GeoDRM service acts as the workflow hub of the GeoDRM system and coordinates the interactions between services. A client first searches for specific data by accessing the Data Discovery Service. In GeoDRM, we envision the Data discovery service to be either one of two or both solutions:

- An extended CSW, where we envision the metadata defined in the CSW to be extended so that users can search for data based on some GeoDRM related keywords, (e.g. if extracting feature is permitted). It holds true for service catalogues where service metadata must express relevant GeoDRM metadata criteria (e.g. service requires “pre-licensing”, or “release data and license later” etc...).

- A provider would have a product catalogue where they will define a generalized licensing policy which provides several licensing schemas mapped to assets so that a negotiation service (described below) can negotiate terms with users based on this generalized schema. This means that a product catalogue will persist to describe the general licensing rules applying to a certain asset. Each license dynamically generated for user who selects a product is then a subset of this product catalogue.

In such architecture, we define two main use categories: a) protect and publish Asset; and b) search and acquire an asset. In the case of data publishing, providers perform the following tasks:

1) Define license terms and pricing schemes.
2) Using some management tools the vendors create the appropriate REL profile schema to support his custom needs
3) Publish the REL on the GeoDRM system
4) Create metadata instance using the SDI metadata profile which has an extension to search data sets based on right descriptions

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

1) Access the catalog service on the SDI and search for certain data offered by vendors who can provide licenses suitable for the user’s needs.
2) The catalog returns the provider of 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 data, they send a request to the GeoDRM gateway which in turn forwards it to the GeoDRM service. 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, GeoDRM system and 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: License First then Release Data

1) As shown in Figure 3-5 user searches for the data provider using the OGC catalog service for the web (CSW) to locate the data set and provider of interest.
2) Once the provider is located, user requests the license from the Geogateway.
3) The Geogateway in turn forwards the request to the GeoDRM service which returns the requested license back to the Geogateway
4) The Geogateway forwards the license to the Client.
5) Once the license has been received, the controller on the client side may enforce some right constraints as prerequisites to requesting data. For example, make online payment.
6) Finally the client sends a request for feature data based on some spatial criteria, e.g., spatial extend.

This case is most suitable for situations where data acquisition from a certain service requires the users to have a valid usage license. In this scenario, possession of a license is a prerequisite to acceptance of data requests.

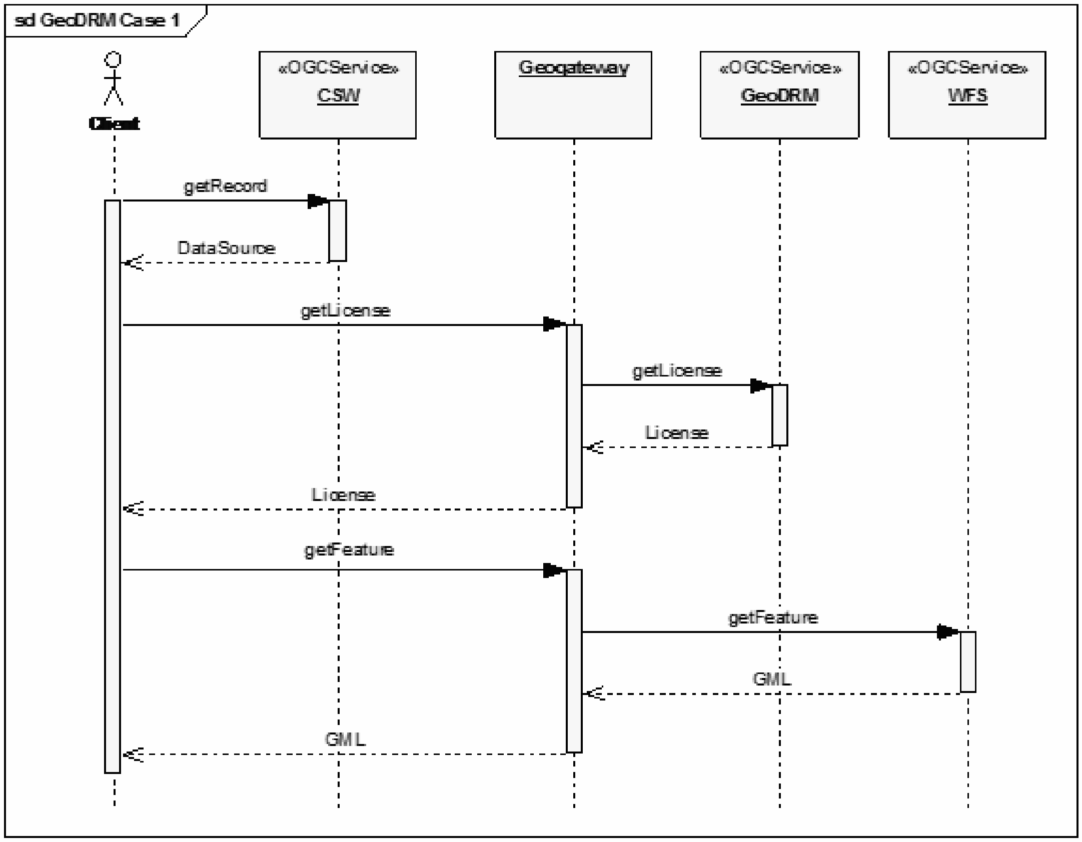

Figure 3-5 Case: 1 License First then Release Data

Case 2: Data First and then License

1) As shown in Figure 3-6 user searches for the data provider using CSW to locate the data set and provider of interest.
2) Once the provider is located, users request the data set by defining the bounding box of the area of interest for example.
3) Users receive data in encrypted form. Data cannot be used unless the appropriate license is acquired.
4) User requests the license from the Geogateway
5) The Geogateway in turn forwards the request to the GeoDRM service which returns the requested license back to the Geogateway
6) The Geogateway forwards the license to the Client.
7) Once the license has been received, the controller on the client side may enforce the license terms on the acquired data.

This case is most suitable for situations for users who already have a data but need to upgrade or modify their license terms. For example, a user may possess a dataset for non-commercial use and requests a license for commercial use once needed.

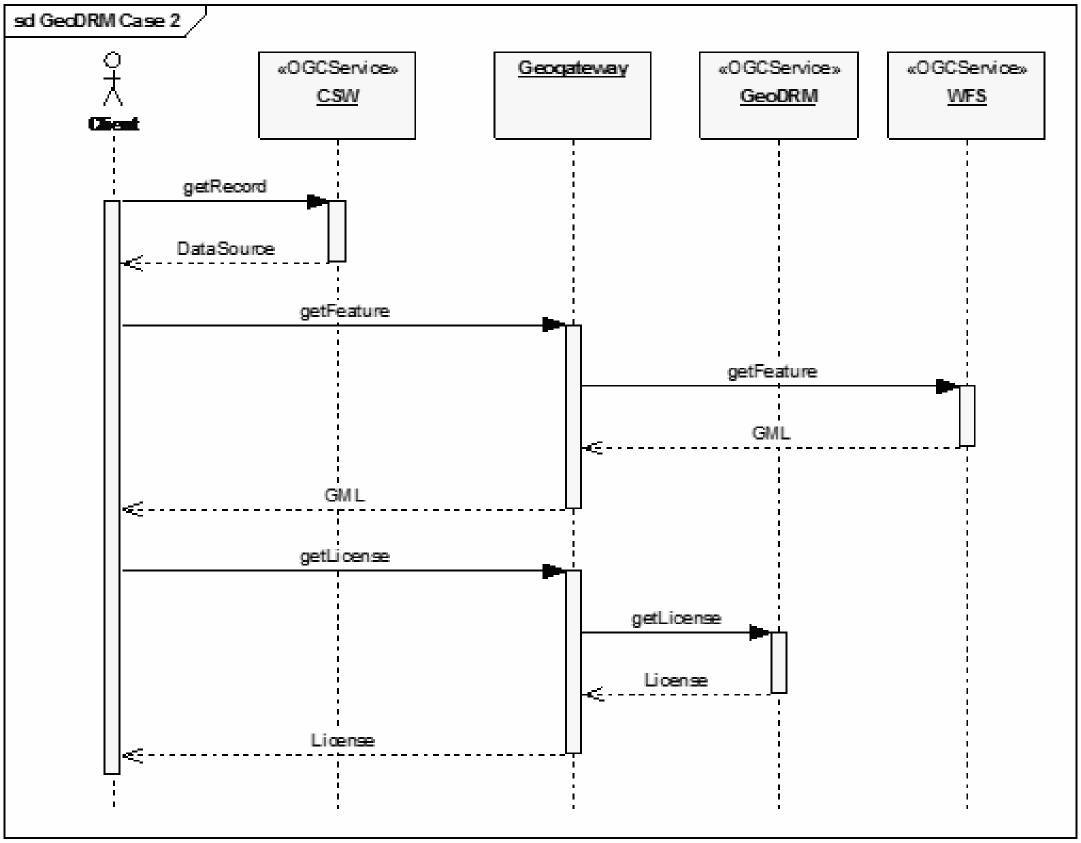

Figure 3-6 Case 2: Data First and then License

Case3: Data and License Combined

1) As shown in Figure 3-7, user searches for the data provider using the CSW to locate the data set and provider of interest.
2) Once the provider is located, users request the data and license together. The user first selects the data set by defining a bounding box of the area of interest. The WFS sends the datasets to the packaging service which then waits for a license.
3) The Geogateway forewords a license request using to the GeoDRM service.
4) The GeoDRM service prepares the license and sends the license to the packaging service. The packaging service packages the data with the license and forwards it to the user.
5) Once the GeoDRM service receives the data set it packages both the license and the data together and forwards them to the GeoDRM gateway which in turns forwards it to the client.
6) The client's Component may unpack the package and enforce the license terms on the data.

In this case, the users interact with the GeoDRM gateway which ensures a proper workflow to request both data and license from a certain provider according to business model rules set by the provider. Also the WFS is assumed to be extended to allow for relevant GeoDRM functionality for example each dataset sent must have minimal instructions of where to obtain licenses (e.g. licensing server URI is included in the response).

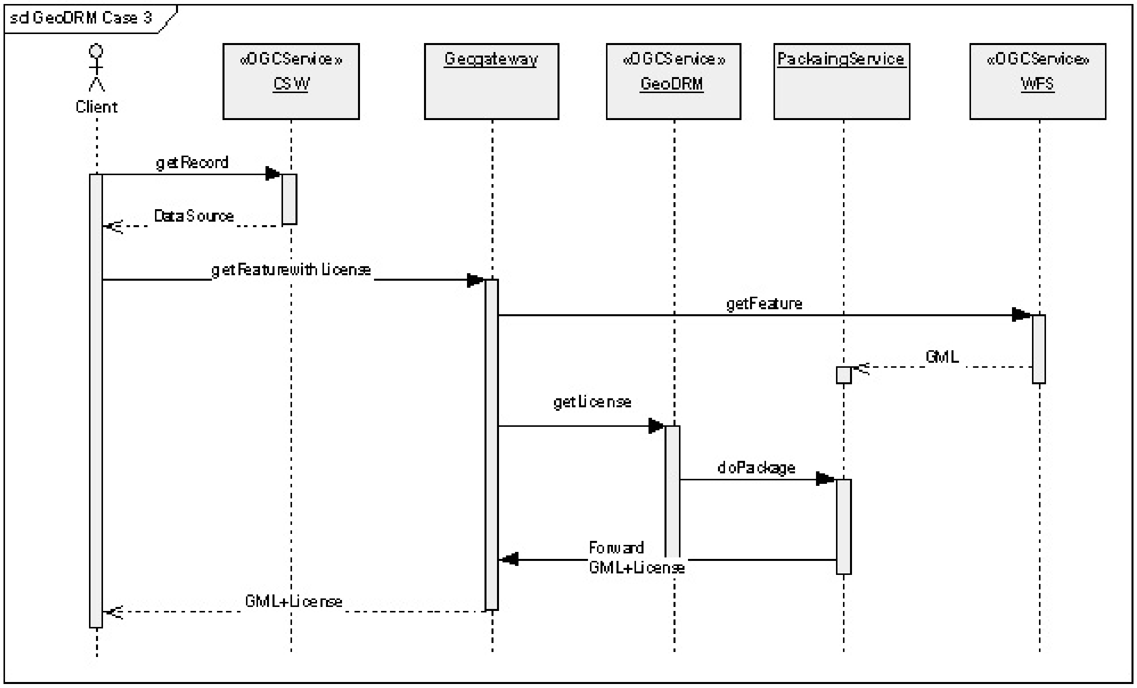

Figure 3-7 Case 3: Data and License Combined

Irrespective of the specific implementation of the three cases above, it can be evident that it is important to separate between the license and the data. In earlier DRM systems both data and license where hardwired together(Rosenblatt, 2002). This model would not have enabled the first and the second cases mentioned above. When licenses are separate from data makes it possible to implement the above cases. Hence, the GeoDRM architecture decouples the license from the data asset. It is also important to notice that since each user requests a different dataset and negotiates different terms the system does not imply a static license schema for the data assets served to users. Each user potentially gets a different dataset with different license terms. Having a large number of users each with unique license terms is one of the factors for considering GeoDRM technology solutions (see 2.4.2) to manage digital licensing of geospatial assets.

In this section, we have derived the GeoDRM reference architecture along with illustrative usage scenarios as expressed in the sequence diagrams. This architecture is based on digital licensing infrastructures and hence digital licenses are a core component which forms the basis for the information model of GeoDRM. In the next sections, we analyze general DRM digital license requirements and establish the GeoDRM information model and then the unified model for GeoDRM license (Geolicenses) based on this analysis.

3.4. GeoDRM Information View

In sections 3.2 and 3.3, we have introduced the GeoDRM architecture. In the remainder of this chapter, we focus on another main aspect of this research. At the heart of DRM system are licenses which are containers for the aggregation of rights expressions and acts as the digital equivalent of “contractual agreements” or “usage licenses”. The information view has two main components that we illustrate in this section. The GeoDRM information model (see 3.4.1) that which should contain all the elements that form information components in the GeoDRM architecture. In addition, the

Geolicense model (see 3.4.3) which represents a generalized view of the geolicense to which we build a geospatial rights expression schema in chapter 4. Generally a digital license file that contains(Guth, Neumann, and Strembeck, 2003):

- A reference to the content that is being licensed
- The conditions of use on that content
- Miscellaneous additional information (Copyright or other legal statements)
- Decryption keys to decrypt an encrypted content package and make it available to the user

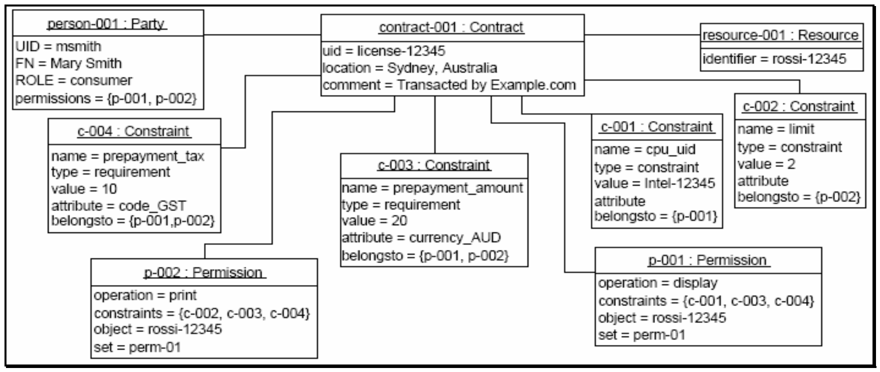

Figure 3-8 DRM Rights Object (Guth *et al.*, 2003)

An active instance of a DRM license is referred to as the "Rights Object" (Figure 3-8). From the GeoDRM architecture, we can safely assert that the information model of GeoDRM and that of DRM is not fundamentally different for two major reasons. First, the GeoDRM licenses are serving the same general purposes which are projecting contractual agreements between parties over assets. The fundamental difference is in the nature of those assets which could be geospatial web services or geospatial datasets. Second reason is that the GeoDRM architecture uses similar service management infrastructure.

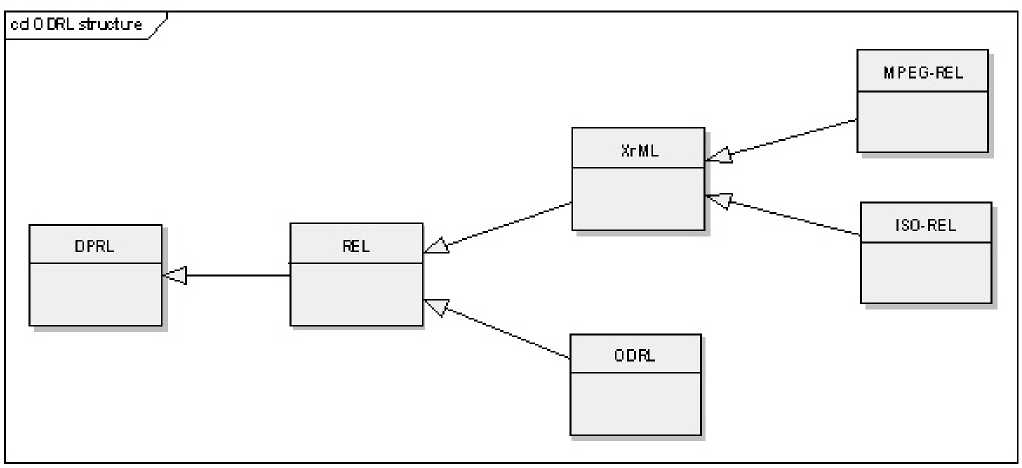

Figure 3-9 Taxonomy of current Rights Expression Languages (RELs)

In chapter 1, we have briefly enumerated the rights expression languages available which are mainly ODRL, XrML, MPEG-REL21, and ISO-REL 21000-5. The latter three languages are very similar, since MPEG-REL and ISO REL are both based on XrML. The Taxonomy of RELs is illustrated in Figure 3-9.

Digital licenses are expressed by means of Rights Expression Languages (RELs) which aim to provide a vocabulary and semantics for the expression of terms and conditions over (digital) assets. RELs aim to enable a machine-based processing of digital contracts (Guth et al., 2003). Others define a REL 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 was invented when Digital Property Rights Language (DPRL), a LISP 1 based language, was developed by Mark Stefik of Xerox's Palo Alto Research Centre. 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 made DPRL 2.0 XML-based, because XML is extensible and interoperable with other emerging standards. From DPRL emerged ODRL and XrML. Based on XrML ISO-REL and MPEG-REL have been developed. (Chong, 2005) identifies four general components of a REL, Figure 3-10:

- Subject, which is an actor who performs some operations;
- Object, which is the content acted upon by a subject;
- Right, which is what a subject can do to an object; and
- Constraint, which describes limitations on the rights granted.

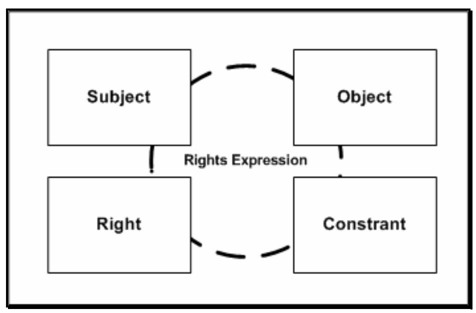

Figure 3-10 Main elements of a rights expression

RELs depend on the notion of licenses as unites of aggregation of rights. Digital licenses and licensing infrastructures have been previously examined. The elements in figure 3-10 have different names in different RELs. For example, The Object in Called an Asset in ODRL and an Object in XrML. the Subject is called a Principal in XrML and a Party in ODRL. ODRL “constraints” are mapped to “conditions” in XrML.

Beyond the above four elements we have noticed within RELs specifications the universal existence of a security model. This security model consists of trust information and asset protection information ranging from encryption keys to watermarking and fingerprinting techniques (explained later next section). Also unique identification information is an essential part of RELs so that we can uniquely identify assets, license objects, and parties.

By considering the general elements of RELs mentioned above and the four elements in Figure 3-10 we can assert a general digital license information model independent of RELs. In the next section

[1] Acronym for *list processor*, a high-level programming language especially popular for artificial intelligence applications. LISP was developed in the early 1960s by John McCarthy at MIT.

3.4.1, we illustrate the general GeoDRM License information model which is independent of any specific REL with illustration of its individual elements.

3.4.1. GeoDRM License information Model

A license data model is specified by means of a Right Expression Language (RELs) in which case the structure of the language schema and its semantics determine the exact data model of the language. From a conceptual perspective, we provide the GeoDRM license information model independent of a REL. In implementation However, DRM licenses cannot be modeled in isolation from a rights expression language and since it carries usage rights (and keys to unlock the protected content in case of encrypted packages), the license also needs to be protected from tampering with its structure-giving rise to the security model of the license. In this section, we have projected the information model elements for DRM into the GeoDRM to enable modeling of the general GeoDRM license information model while extending it to show where spatial properties are needed from a high perspective. Figure 3-11 illustrates the general GeoDRM license information model. The rest of the sections are as well used to define each of the elements of the GeoDRM information model which are listed below:

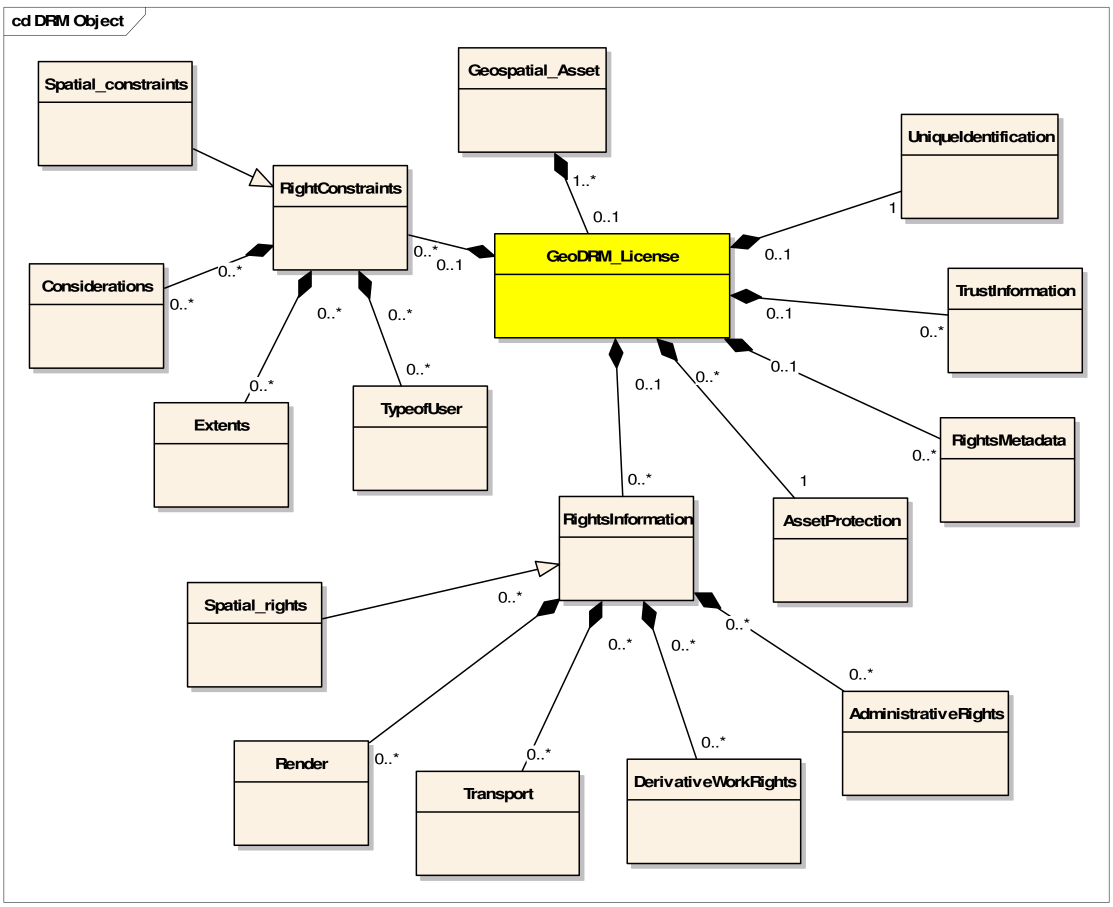

Figure 3-11 The GeoDRM information model

1. Rights Information: A definition of types and meanings of permissions that may be granted in a license, and spatial and non-spatial permissions and how to express the spatial permissions.
2. Rights Constraints: A definition of the types and meanings of spatial and non constraints that may apply to each permission, principal or resource
3. Unique Identification: unique identifiers are required for the following reasons:

   a. Provide unique identity to the geospatial assets holders and licensees in an open distributed environment like the Web.
   b. Enable licenses to refer to assets that are being managed in GeoDRM.
4. Geospatial Rights Metadata: general information to enable the search and discovery of assets in a web environment based on a certain GeoDRM criteria (e.g. rights).
5. Trust Information: signature and trust information for authentication of identity and to verify that the license has not been modified in any significant manner. Also trust in the social sense, which can be asserted when parties in a transaction are well defined.
6. Asset Protection: these are mechanisms to embed information with the assets so they can be recognized and any misuse can be detected and attributed to the infringing parties.

3.4.1.1. Rights Information

This is the major focus of this research and a spatial rights representation approach is presented in chapter 4. The Rights in the broadest sense as identified by DRM are actions (or activity) or class of actions that a subject may perform on or using the associated asset(Contentguard, 2001; Iannella, 2002; Park *et al.*, 2004). Recall that in the beginning of chapter 2 we highlighted the similarity between access control and DRM. Rights therefore, enable users to access assets in a particular mode, such as read or write(Park *et al.*, 2004). (Rosenblatt *et al.*, 2002) identifies, render rights, transport rights, and derivative rights as the three types of rights. According to Rosenblatt, the three mentioned categories of rights are assumed comprehensive, but the rights within the categories (i.e. play, extract, etc…) vary according to the type of content and its applications.

In addition to the above three types of rights, issuance rights (the right to issue grants of other rights) and delegation rights (the right to delegate a grant to another party) are examples of essential rights over rights. We collectively call these types of rights Administrative Rights (Chong, 2005) which add to the core types of rights addressed above. These rights categories are a general functional categorization of rights that fits any digital rights domain such as GeoDRM.

1. **Render Rights:** relates to representing the content on some output medium (i.e. Play, view, print, etc….)
2. **Transport Rights:** (i.e. Copy, Move, Loan, etc…) are the rights to move or copy content from one place to the other the differences for example among the copy, move and loan have to do with which users have access to the content at any given time. In the first instance (copy) user 1 give copy of content to user 2, both have access to the content simultaneously. While (move) means user 1 gives up access once content is moved to user 2. (Loan) means user 1 does not have access to content temporarily after lending the rights to the content to user 1 until user 2 gives the rights back to the content server.
3. **Derivative work Rights:** (i.e. Extract, Edit, Embed, etc…) have to do with manipulation of the content to create derivative work for example (extract) has to do with the right to use pieces of content on there own and extracting it out of its context. (Edit) are the right to make changes to the content. (Embed) is the right to embed the content into another product.
4. **Administrative Rights:** rights over rights (e.g. the right to delegate a certain set of rights to others).

A special type of rights for the Geospatial domain are Geospatial rights which are shown in the diagram as a specialization. Example of which is an Extract feature right which is of type derivative work rights. In section 5 we implement various spatial rights.

3.4.1.2. Rights Constraints Information

Constraints on rights are attributes that are attached to each of the fundamental rights mentioned above. Attributes include considerations, extents, types of users (Rosenblatt *et al.*, 2002). Spatial constraints are also needed. Since the constraints are on the use of geospatial assets.

1. **Considerations:** is whatever 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 agreements between the publisher and the user. For example, a publisher might allow someone to use his content to produce work in return of a copyright notice in the produced work
2. **Extents:** relates to how long, how many times, or in what places the rights apply.
3. **Types of users:** it allows for specifying sets or rights and right attributes to particular user or category of users. For example, you can have educational institutions as a particular category of users.

3.4.1.3. Unique Identification Information

Unique identification of licensed content is an integral part of any DRM license. Digital Object Identifier (DOI) is a standard for online content identification and linking based on URI and URN governed by the International DOI Foundation. Digital content using the DOI system is given a unique alphanumeric character string that is used as an identifier. The identifier is comprised of a prefix and a suffix, separated by a forward slash. The prefix is assigned by the registering agency and identifies the specific organization, and the registrant to identify the unique content provides the suffix. The DOI also comes with metadata that describes the content. The DOI of an object is permanent so that the content can always be located if the URL of it changes (the user will be redirected to the new location). The technology was developed to protect the copyright of material published on the Internet, to compensate content creators for their work, and to keep track of content.

Using the DOI to uniquely identify any digital asset be it data or service means assigning a DOI to the asset. Regular URLs as a mean of identifying digital content is not successful because they point to specific location of an asset or files. If the location of the asset changes the URLs become invalid. DOI point to a master table called the *DOI directory* where each DOI record is assigned a URL that leads to the asset of the URL. URL changes are always synchronized with the DOI directory.

For example **11.2067/plot.tr11.0019** is formed of a prefix and a suffix after the slash. The prefix (**11.2067**) points to a publisher or content author while the suffix (**plot.tr11.0019)** points to a specific content or service. Many publishers have already adopted DOIs by putting a suffix to the ISBN or ISSN of their publications. DOI so far is proving to be successful in the publishing industry. In the realm of the DRM, DOIs can be used to uniquely identify the license objects. Similar techniques can be used to uniquely identify assets in GeoDRM licenses where each geospatial provider would have his own unique identifier that identifies his own assets.

3.4.1.4. Rights Metadata Information

When publishing assets in an open and distributed network like the Web, users need to be able to search and discover assets based on different generalized information. For example users can search music based on genre, date of creation, etc. 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 data metadata catalogues based date of creation, keywords, etc. The role of metadata is to provide information about collection of assets to enable search and discovery. OGC has defined the Catalogue Service for the Web (CSW) to enable clients search and discover data based on well-defined metadata elements. These elements are defined in the ISO 19115. We recommend an extension to the ISO 19115 metadata standards and its implementation in the CSW to support searching data based on some geospatial rights metadata. Although it is outside the scope of our research, we believe a GeoDRM CSW profile to be an important aspect that has yet to be considered by the OGC GeoDRM working group. In general, we recommend the following categories as guidelines to for the rights Metadata:

- Licensee metadata: consists of general information about types of users who can have licenses and access rights to the asset (e.g. academic institutions, commercial users).
- Licensor metadata consists: of general information on the authority, that controls the data. This type of metadata is similar to subsections of the ISO 19115 metadata standards.
- Rights metadata: consists of general information about the types of rights and constraints that are generally applied on collection of assets.

3.4.1.5. Trust Information

Trust has both Technical and social meaning. From a technical perspective, a trusted system is a system that can hold digital works and which can be trusted to honor the rights, conditions, and fees specified for a work. Trusted systems can take different forms, such as "trusted players" that play digital works, or "trusted readers" for reading digital works or "trusted servers" that may provide access to digital works on a network. Different implementations of trusted systems have different requirements for security and different approaches. In the most secure approaches, all of the hardware and software on the platform is certified to honor digital rights. Other approaches focus on the use of so-called secure envelopes or containers, emphasizing transmission and storage of information. All such approaches have some elements that are assumed trusted and can be circumscribed by boundaries of trust. These boundaries may be the boundaries of program code assumed not to be altered, data files assumed not to be accessible, language interpreters (such as Java) assumed to follow certain rules, or physical hardware assumed not to be compromised. The security of a trusted system depends in large measure on its vulnerability across these boundaries (Vingralek, Maheshwari, and Shapiro, 2001).

Public Key Infrastructures are set of servers, software, protocols and application programs used to manage the Private Key's and Public Key's of a group of users (Keys a cryptography mechanisms used to encrypt or to digital sign digital assets). Users are generally able to create and update their own key pairs, and a Certificate Authority is used to sign new Public Key's. Some mechanism is made available by which users may conveniently and reliably retrieve and use their own Private Key's and other users' Public Key's (Sandhu *et al.*, 1994).. For example in recent years, research in authorizations has been pursued under the name of trust management. Both traditional access controls and trust management deal with the protection of digital assets within the trusted environment of an asset provider (Park *et al.*, 2004). None of these systems deals with protection of assets on the client machine outside the trusted environment of the provider. (Schneck, 1999) introduced a new perspective on access control problems considering requirement for persistent access control, in the sense that protection of any digital asset occurs wherever this asset exits (e.g. on a server or when content is moved to a client environment).

From a social perspective GeoDRM have significant impact on Trust between parties participating in geospatial information sharing be this for intergovernmental or private sector to government as asserted from (Harvey, 2003; Harvey *et al.*, 2004) and illustrated in the GeoDRM definition in chapter 2. This also applies to commercial geospatial information transactions. The Effect of trust on GeoDRM enabled SDI could be on many fronts. Examples of which are:

- Accessing a geospatial service after signing a digital license specifying a “level of service agreement” and “terms of use” has an effect on the trust among the parties involved and on the level of service (i.e. do I trust this service enough to build an emergency application on it?)
- A government entity “G” licenses a valuable dataset with an IPR license giving a restricted set of uses to user X for non-commercial use. Such transaction and use of digital licenses vests more trust into participating parties since all participant and rule are well defined.

A minimum level of information is required in any GeoDRM license to insure parties involved in an agreement can assert trust in each others regarding these transactions. We also envision that trust would be a context sensitive elements. That means for example in certain situations the quality of the dataset could be the major element of trust. In another cases the party from which the data originates is the element of trust.

3.4.1.6. Asset Protection Information

Digital content can be encrypted to scramble the content packages, which then need to be decrypted by private keys embedded in the license to the content. The content can’t be decrypted and 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). It describes methods and technologies that allow hiding of information, for example a number or text, in digital media, such as images, video, and audio. The embedding takes place by manipulating the content of the digital data. That means the information is not embedded in the frame around the data. The hiding process has to be such that the modifications of the media are imperceptible.

Research in geospatial content water marking is still in its infancy. However, in digital imagery it is a more mature area than vector geographical information, even with multiple commercial vendors offering watermarking protection. 2D vector and point datasets have received less attention from the research community(Lopez, 2002).

3.5. Geolicense Specific Requirements

In the previous section, we identified the main elements of the GeoDRM information model. The goal of this section is to identify the requirement two main aspects that are specific to geospatial information as stated in section 1.2. The first aspect relates the ability to resolve the problem of non-discreet assets, while the second relates to combining multiple datasets.

In the first aspect of the problem, we addressed the fact that in non-spatial DRM licensing is for assets where the assets are discreet units such as a book, or multimedia file for example. On the Geospatial domain, the asset is a little bit more complex. A district of a city when licensed is originally a part of a bigger whole, which is the dataset of the whole city (Figure 3-12). Further more one can have a license for patches of the district and not for an entire district. Making the geolicense more of a mechanism to cut through a continuum which the entire larger dataset. In this research, we tackle this problem. Basically, licenses act as a clip operator on the larger dataset where the clip is the license extents.

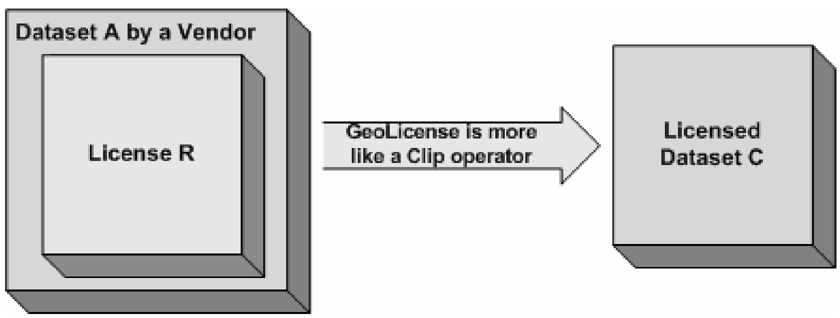

Figure 3-12 Geolicense cutting through a continuum of the larger dataset A

We previously mentioned that the nature of assets is a fundamental difference regarding GeoDRM. In this research, we are concerned with developing an approach to the expression of rights on GML data assets. This requires us to define what an Asset in GML with regard to the rights expression. Hence, we can understand the requirements that need to be satisfied by a certain REL.

Figure 3-12 illustrates the GML data Asset. In any rights expression we specify rights over assets. From a GML perspective an Asset can be defined in three distinct methods to enable flexibility of defining the extents of the license

a) As a GML bounding shape the bounds the dataset.
b) As a GML feature and
c) As a gmlFeature collection.

These three methods can be combined together so that assets can be defined such as for example “the extent of this license is R and it pertains to this particular feature Types Y in dataset a that allows you certain rights R. If you get a feature type Y outside the valid extents of the license then the rights R don’t apply”. In that, sense the license extents acts as a clip mechanism cutting through the geospatial dataset continuum. This satisfies the core aspect .stated in section 1.2. Hence, geospatial licenses must be able to express geospatial boundaries and geospatial properties to cut to the spatial continuum of the dataset.

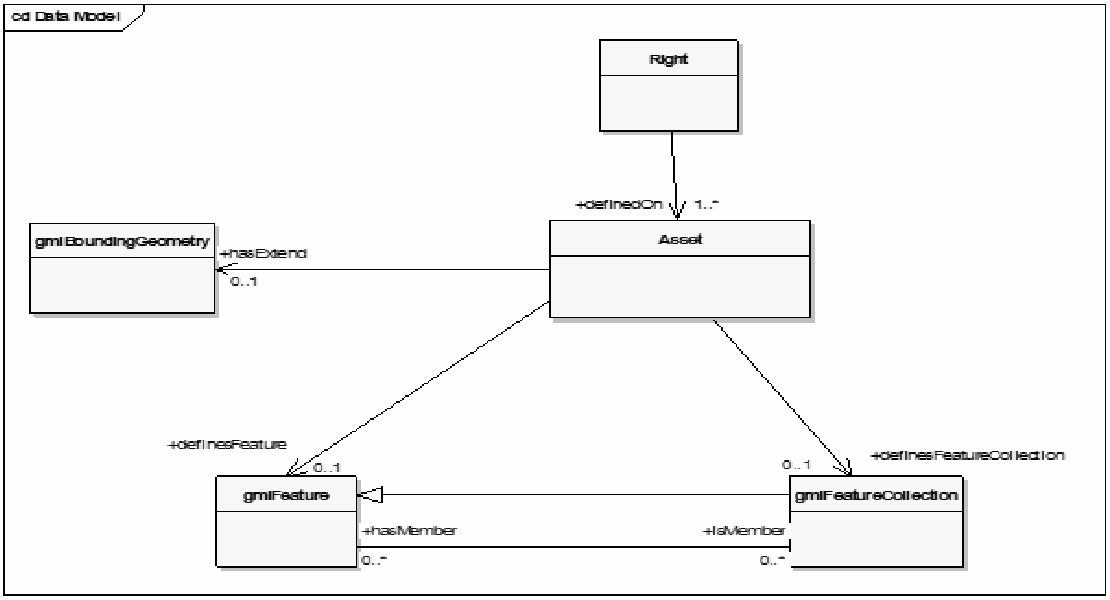

Figure 3-13 GML Assets in GeoDRM

Also in the GeoDRM architecture, scenarios (see 3.3). A user would acquire a license and request data from a WFS. We envision that the WFS would be able to authorize the data release after authenticating the license and extracting the correct data request from the license (e.g. bounding box). Hence, the license needs to specify the extents of the asset covered unambiguously. In addition, non-spatial DRM, license references assets by using unique identifiers as mentioned in section 3.4.1.3. It is also possible to identify geospatial features, encoded in the GML using unique identifiers (OGC 2005-GML), in which case the gml:id property of features and feature collections can be the database unique identifier (e.g. TOID in case of ordnance survey master map).

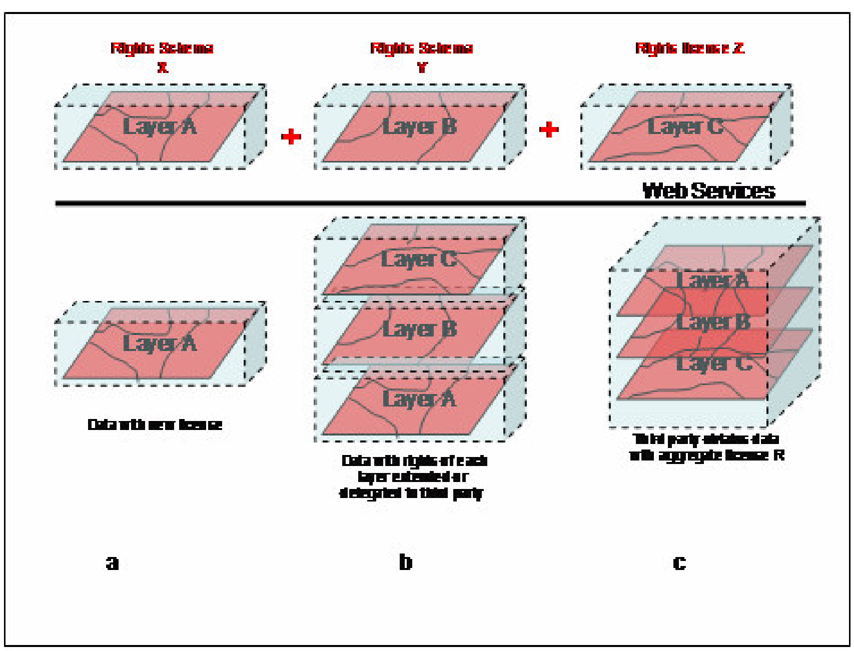

Figure 3-14 different ways to handle heterogeneous licenses

The second aspect discussed in section 1.2 relates to the ability to merge geospatial data while maintaining the semantic consistency of the licenses. It is important to note here that the second aspect although important, its solution is considered to be outside the scope of this research. In chapter 5 (conclusions and recommendations) we recommend an approach that requires further research to solve this specific problem. Integrating geospatial content from multiple data sources may require licenses to be modified. Figure 3-14a, shows the simplest case occurs when a client receives data with well-defined license. In 3-14b, a client may receive three different data sets (layers A, B, and C) and maintain the license of each individual set. This however, may lead to some conflicting rights when users attempt to merge the data. In the third case 3-14c, the GeoDRM system of the client may be able to generate a semantically consistent license that spans the three data sets.

From the above discussion, and the work done on this chapter following is a list of requirements for declaration geolicenses on Geospatial Features. It is important to note that these requirements focus mainly on Assets in the GML sense. Although other requirements for other data types are outside the scope of the proof of concept implementation, we believe that many of these requirements are also applicable to Maps and Coverages:

1. **Rights Granularity:** According to the definition of a GML asset specified in this section, the granularity of the expression of rights spans features, features collections, and asset boundaries. This enables complex specification of expressions as previously illustrated. In addition, same reasons suggest that granularity might be refined to individual properties of each feature. However, and in the long term, such model may burden GeoDRM systems with the task of tracking the use of each property. We believe this to be a model that cannot scale. We therefore believe that REL should only enable granularity on feature instances and their collections thereof along with the boundaries. This requirement will be considered in Chapter 5.
2. **Types of Permissions**: right permissions should consider whether the act will affect the geospatial content or not. For example, printing does not alter the data, while coordinate transformation will. This requirement will be considered in Chapter 5.
3. **Administration rights:** REL should enable update or change of rights permissions. To be able to regrant rights to others for example. This requirement will be considered in chapter 5.
4. **Composite License**: The REL should support building license from multiple heterogeneous licenses of data coming from different providers. The process of automatic conflict resolution and construction of homogeneous license is outside the scope of this research. However having structured licensing framework is a step towards the realization of this aspect
5. **Spatial extent of licenses**: the REL should enable rights definition based on the geometricboundaries of datasets. This requirement will be considered in chapter 5.

3.6. Geolicense Information Model

Earlier this chapter we have provided the general GeoDRM license information model independent of the RELs. This information model forms the basic structure of the information entities that need to be researched to enable a full-fledged GeoDRM system. We abstract the general geolicense information model using a REL in this section to be able to perform the proof of concept. We have addressed that RELs provide the essential semantics for expressing digital licenses. Attempts to model licenses without reference to a specific REL schema in implementation phase would result in a considerable redundancy in the development effort. Hence, to model the Geolicense for which we provide the implementation in chapter 4 have adopted the semantics of Open Digital Rights Language (ODRL). ODRL in general is discussed in more details in chapter 4.

Figure 3-15 illustrates the Geolicense model implemented in the next chapter that has the following classes:

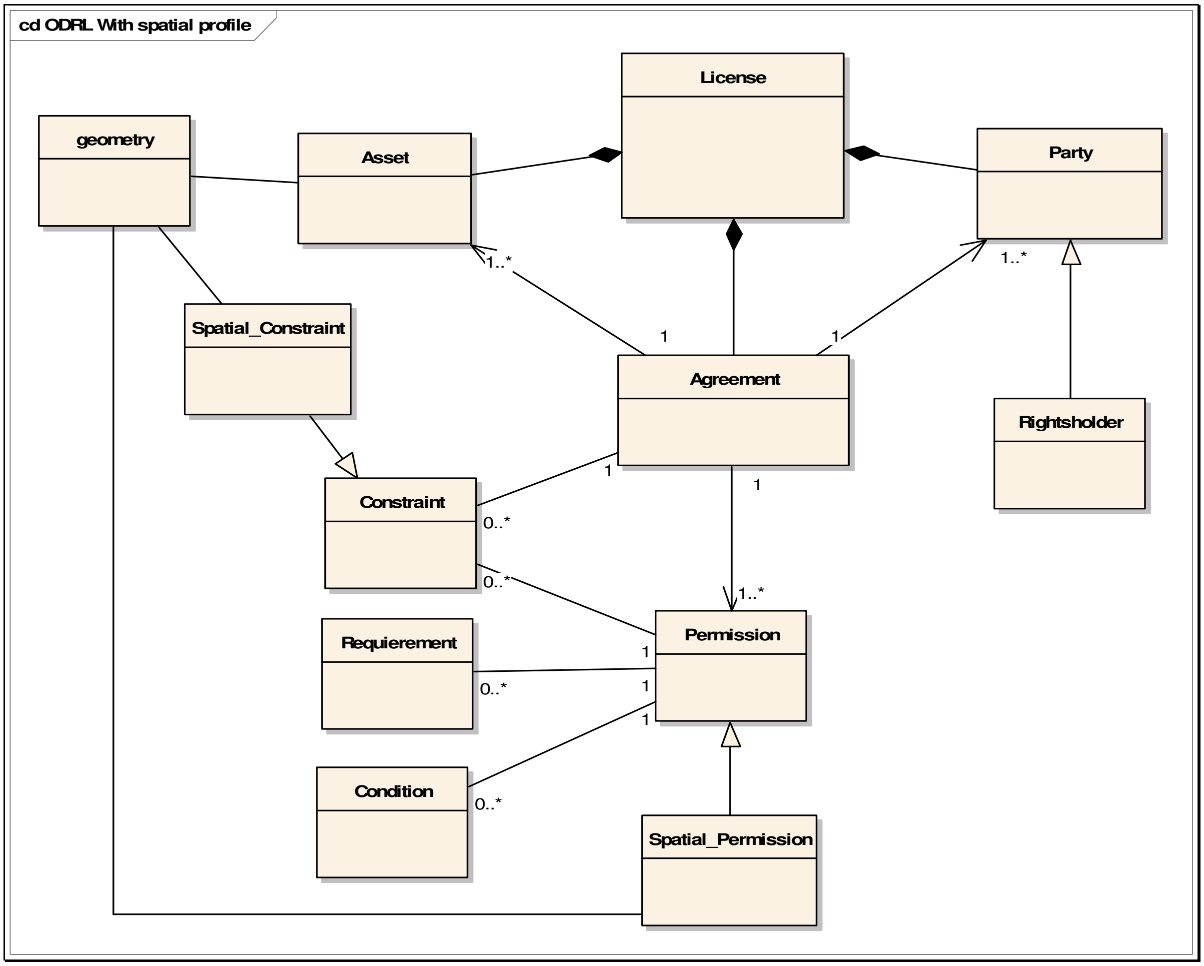

Figure 3-15 the geolisence model

- The license class (rights object container): is the major entity of the Geolicense and at the very least must be composed of one party, asset, and an agreement classes. It acts as the container of the license entity and aggregates the basic license elements. Parties and assets can be defines globally and have the license class as their container.
- The Agreement class: the agreement is the part containing the terms and conditions of the license. In the Geolicense, if parties and assets are not defined globally they must then be defined as part of an agreement. This also contains permissions. In all cases permissions must be contained within agreements as agreements act as units of aggregation of permissions.
- The Asset: is the object being licensed to which we have adopted a certain definition in this thesis as expressed in section 2.3. Assets in the Geolicense have geometric properties such as spatial boundaries to enable expression of geospatial resources.
- Party: is an entity that has a role of a subject who has any role relating to the asset. (Owner, licensee, licensor, etc).

- Rights holder: The Rights Holder is a recognized Party (who receive compensation for the use of the asset) and has facility to specify any set of entitlements that they are due for the use of their Asset.
- Permission: is an act to which a party is entitled to over an asset
- Spatial Permission is a specialization of Permissions which should have Geometric and other properties to specify permissions over geospatial assets.
- Constraint is a restriction which can be applied to both permissions and agreements (e.g. perform a certain act once. Or in a certain quality)
- Spatial constraints are specializations of constraints that have geometric and other properties to be able to express constraints on spatial permissions.
- The Requirements are sets of preconditions that need to be fulfilled before permission is due to a party.
- The conditions are conditional events that if true render the permissions invalid.

3.7. Conclusions

In this chapter, we have presented the GeoDRM architecture in the form of loosely coupled services each of which performs a key task in management of digital licenses. Later in the chapter we presented the GeoDRM license information model and elaborated on the individual elements these elements constitute the essential elements for a full-fledged GeoDRM implementation. This information model is independent of any REL and represents a generalized view. Each of the elements within the information model need further study beyond this research to define its specific elements and implementation details. We used the geolicense information model in conjunction with ODRL to derive a geolicense model based on ODRL was presented illustrating a view of the geolicense for the digital licensing of GML datasets. This model then guides the development of the extension of ODRL represented in chapter 5.

In the next chapter, we address the implementation of the geolicense model by extending the ODRL with spatial data types and necessary extensions

4. GeoREL Development and Proof of Concept

4.1. Introduction

In this chapter we introduce the Geospatial Rights Expression Language schema (GeoREL) which follows on the model developed earlier (see 3.6). and is developed to accommodate the requirements of the licensing scenario developed in this chapter for licensing vector datasets. In section 4.2 we provide an introduction to the Open Digital Rights Language (ODRL 2002) which is an open source rights expression language. Being open source and lightweight makes it ideal for the proof of concept we intend to provide in subsequent sections.

In section 4.3 we present the approach to the extension of ODRL to build the GeoREL, this extension uses GML to build spatial data types to accommodate spatial requirements of rights expression. The use of GML schema in developing the GeoREL schema provided strong spatial extension to the ODRL and it enabled us to define spatial boundaries, for the Geolicense as well as spatial permissions and the ability to express rights on the feature and feature collection level. This means that a high degree of granularity of the rights have been achieved within the Geolicense. Section 4.4 illustrates three scenarios with three different Geolicenses based on "Ordnance Survey's Print/Copy Shop License". These three scenarios demonstrate the ability to form syntactically correct Geolicenses based on the developed GeoREL schema.

4.2. Open Digital Rights Language (ODRL)

ODRL 1.1 specification (ODRL 2002) focuses on the semantics of expressing terms and conditions on licenses of digital assets. ODRL can be used within trusted or non-trusted systems for both digital and physical assets. However, ODRL does not determine the capabilities nor requirements of these environments (e.g. for content protection, digital/physical delivery, and payment negotiation) that utilizes its language. It is solely focused on the expression of rights in digital licenses.

ODRL standard provides two schemas (see Figure 4-1):

- the right expression constructs in the expression language schema and
- definitions of instance elements in the data dictionary

The expression language schema (ODRL-EX package) provides the basic structure of the language. While the data dictionary (ODRL-DD package) provides additional elements essential for building, working XML instances such as new permissions, or constraints. ODRL is also an extensible standard it can be extended with new additional data dictionaries to add more expressive vocabulary to the language. Hence any new extension of ODRL involves establishing a new domain specific data dictionary.

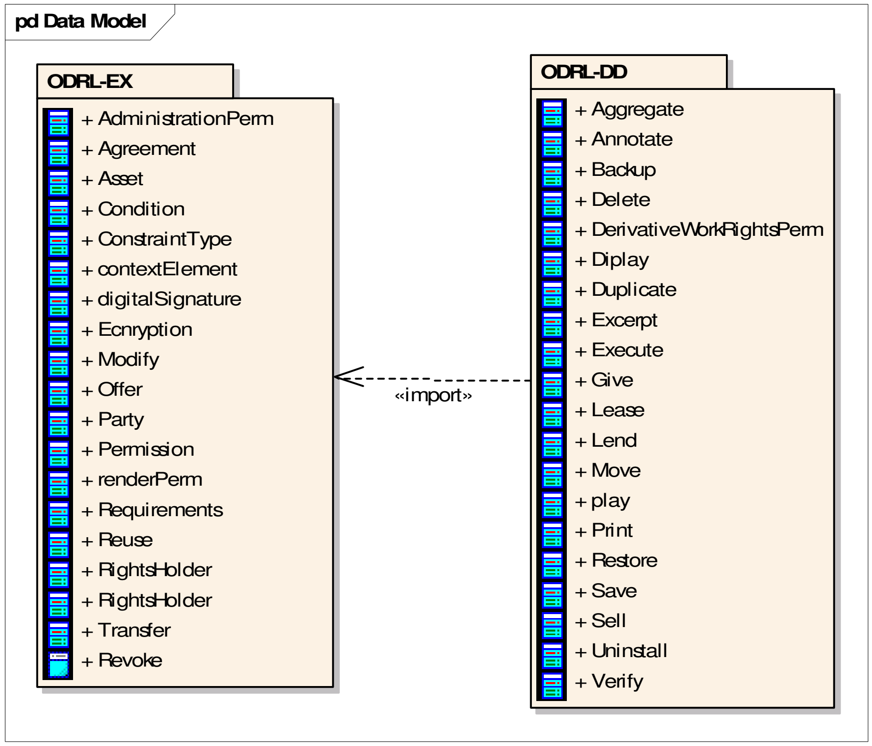

Figure 4-1 The Standard ODRL 1.1 Package Diagram

To build new elements within a new data dictionary and still preserve the language structure the expression language schema defines elements that are utilized as placeholders for additional data dictionary elements, These elements are:

- permissionElement (permissionType)
- requirementElement (requirementType)
- constraintElement (constraintType)
- conditionElement (conditionType)
- contextElement (contextType)
- rightsholderElement (rightsHolderType)

The elements above are defined as "abstract" ensuring that they cannot appear in an instance of an ODRL XML expressions and by default are of "anyType" data type to allow maximum extensibility (e.g. by building more complex datatypes). The Data Dictionary schema utilizes the "substitutionGroup" mechanism from XML Schema to ensure that only the appropriate elements can be used in the correct position in the ODRL Expression Language. The ODRL specification provides detailed explanation and data model for each of the elements below:

For example, the ODRL Expression Language schema defines the abstract element:
<xsd:element name="permissionElement" abstract="true"/>

To extend the language the specification mandates establishing a new application specific DD schema. Using the above expression from the Expression Language Schema a new permission

element to give the “Display” right can be defined in the ODRL Standard Data Dictionary schema, such as:
<xsd:element name=”display” type="o-ex:permissionType" substitutionGroup=”o-ex:permissionElement”/>

The permission “display” is of the type “o-ex:permissionType”, other complex (e.g. Spatial) data types can then be developed and integrated within the language. The specification provides the standard schema of the rights expression under the namespace “o-ex” and the standard data dictionary in the name space “o-dd”. We have built an additional spatial data dictionary to be able to express the GeoLicense in the namespace “georel-dd”.

```
<o-ex:rights>
     <o-ex:context>.
          <o-ex:uid> ... </o-ex:uid>
     </o-excontext>
  <o-ex:agreement>
     <o-ex:context> ... </o-ex:context>
     <o-ex:asset> ... </o-ex:asset>
     <o-ex:permission>
          <o-ex:permission-type>
               <o-ex:requirement> ... </e-ex:requirement>
               <o-ex:constraint> ... </o-ex:constraint>
          </o-ex:permission-type>
          <o-ex:condition> ... </o-ex:condition>
     </o-ex:permission>
     <o-ex:party>
          <o-ex:context> ... </o-ex:context>
          <o-ex:rightsholder> ... </o-ex:rightsholder>
     </o-ex:party>
   </o-ex:agreement>
</o-ex:rights>
```

Above is the simplified XML instance of ODRL. The “<o-ex:rights>” In ODRL vocabulary refers to the root element of the whole rights object (a license instance); however, rights as defined earlier in this work are known in ODRL as “Permissions”.

4.3. The ODRL Spatial Schema Extension (GeoREL)

We have identified the core components of ODRL in 4.2 and we have established that all RELs share the same semantics while the vocabulary for expressing the semantics differs (see 3.4). The same approach used with ODRL can then be used with other RELs to achieve similar goals by using the REL semantics and projecting it to the developed GeoREL model to make it relevant for a particular REL.

ODRL can’t be used directly for the Geolicense as by default it does not provide spatial data types. It also does not provide the ability to describe on geospatial assets as described in this thesis (see 3.5) or any spatial elements in general like spatial permissions. These are not shortcomings of ODRL since it provides generic vocabulary for rights expression. Rather these are issues left to be resolved in domain specific data dictionaries. In this section, we explain the extension methodology of the ODRL language to build a geospatial profile of ODRL which would enable expression of the Geolicense 3.4.3. The detailed data dictionary schema developed at this research are attached in Appendix A.

In Figure 4-2 we illustrate the high level data model of the GeoREL schema by means of a UML package diagram. The two packages ODRL-EX and ODRL-DD as previously illustrated are the core Schemas of the ODRL. To enable geospatial rights expression we Extended ODRL with an additional data dictionary which is the package GeoREL-DD. We then used imported vocabulary from GML schema is enable building spatial types and GML types within GeoREL-DD. The GML application schema package is a representation of a Generic application schema.

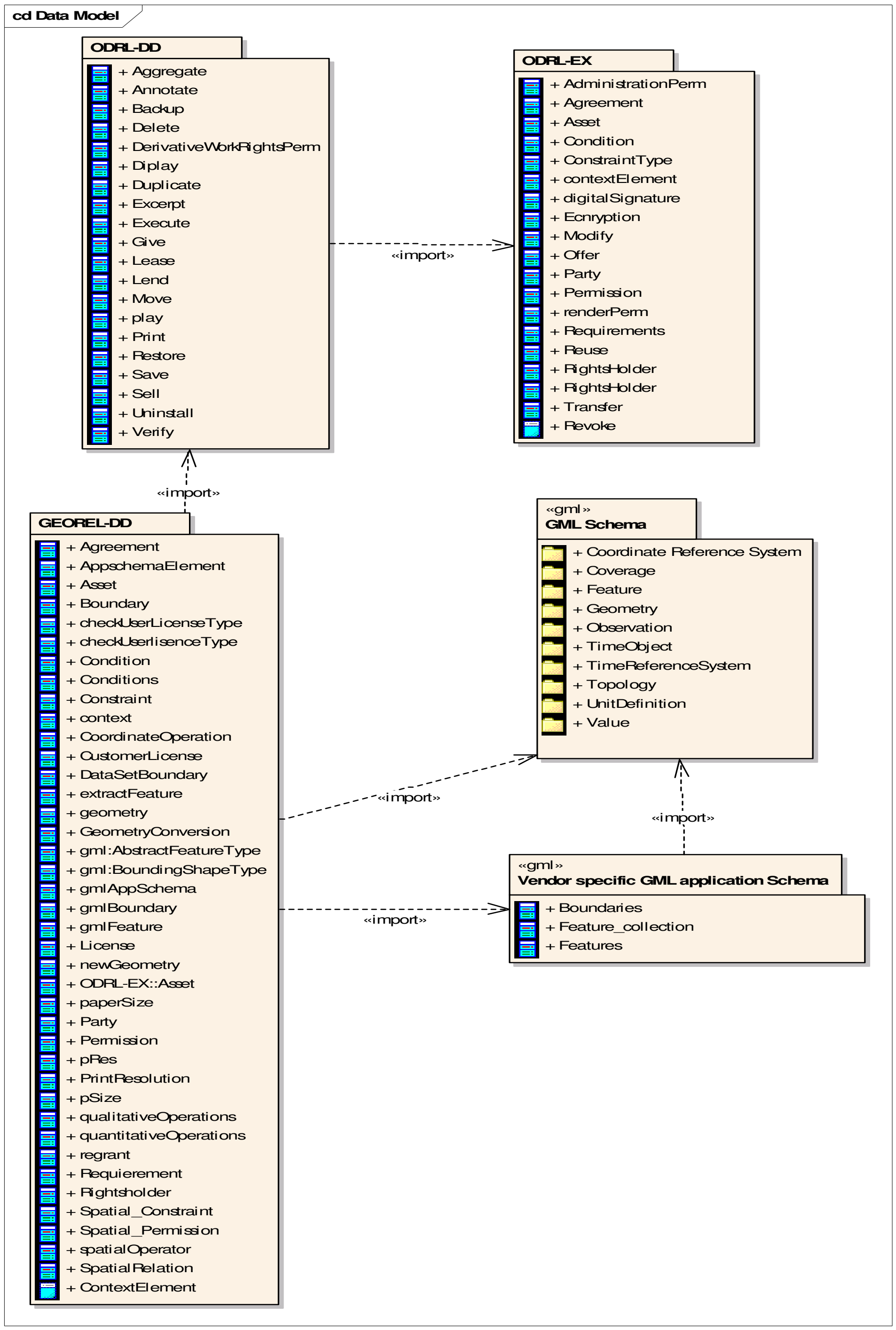

Figure 4-2 GeoREL Package Diagram, the composition of dependencies of the GeoREL schema

In GML the application schema (OGC 2005-GML) is a domain specific Schema based on GML. For the GeoREL-DD to be ready for expressing rights on a certain dataset the application schema of this dataset needs to be imported within the GeoREL-DD, hence it become possible with the mechanism developed within the GeoREL-DD to specify rights expressions on the feature or feature type level of this particular application schema.

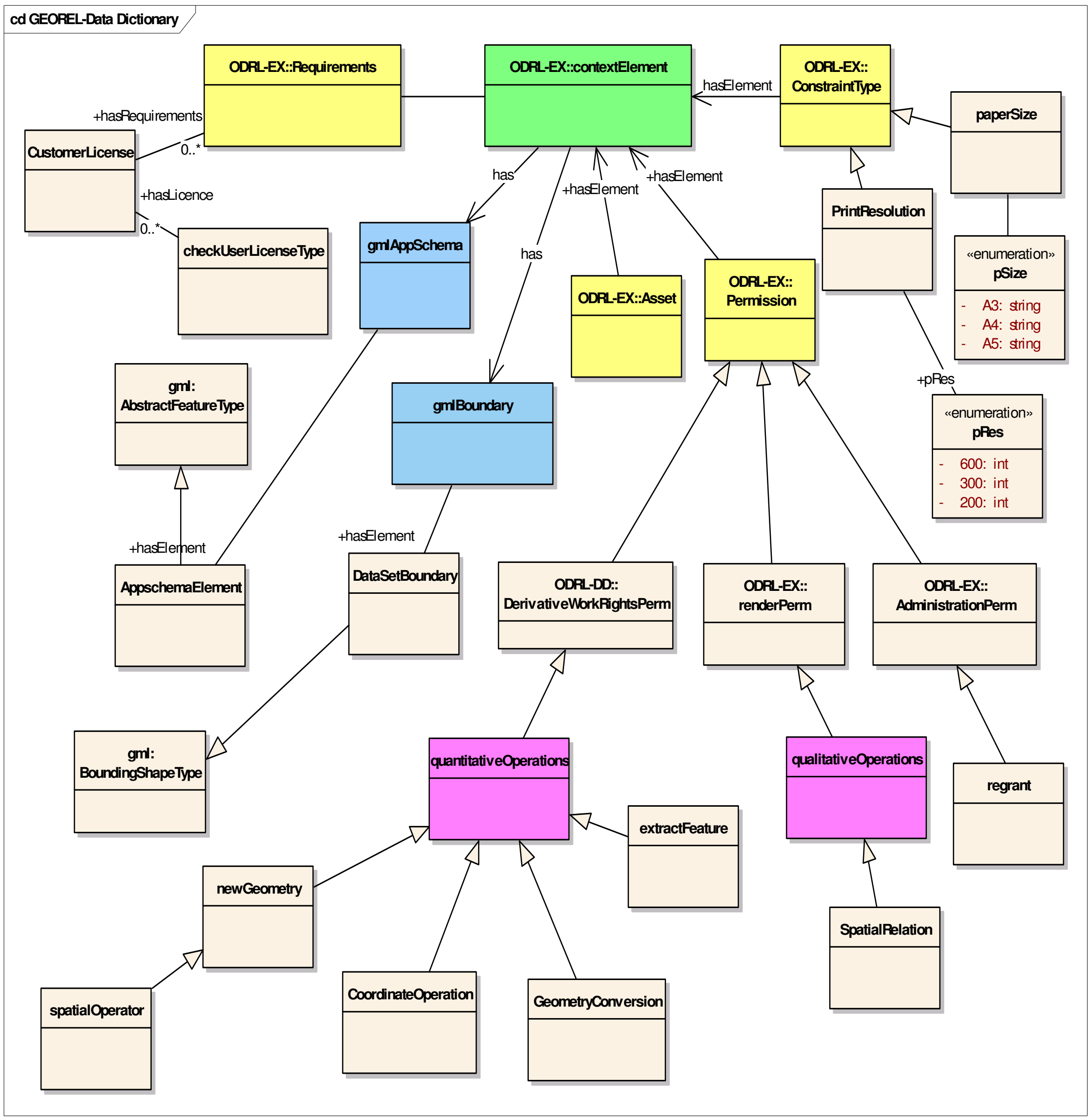

Figure 4-3 the conceptual model of the developed GeoREL data dictionary schema structure

In Figure 4-3, the UML class diagram of the GeoREL data dictionary schema that is used to illustrate the Scenarios in section 4.4 is presented. The class “contextElement” is generic in ODRL and exists as a component for all other major elements in the language it can be used to express any additional information about the element. The diagram illustrates that “Asset”, “Permissions”, “Constraints” and “Requirements” (yellow classes) all have contextElements. Thus, any elements available for the context are available for all the other classes. In the contextElement, we define two spatial elements (blue classes), which we elaborate on later. One is used to define Spatial Boundaries, and the other is used to define GML Features, Feature collections and Feature Types (OGC GML 2005). We also define two classes of spatial permissions (purple classes). In addition, non-spatial permission (regrant) is defined to allow for transfer of rights to other parties.

In the rest of this section, key GeoREL elements are explained to illustrate the derivation of spatial elements. While illustrative examples of the Geolicense instances are used to further illustrate the usage of the GeoREL schema in constructing geolicenses for licensing scenarios to validate the approach against the scenarios in section 4.4

Defining Spatial Boundaries

To be able to define spatial boundaries for the extents of the Geolicense, the ODRL "context" element was utilized. Most entities in the ODRL model can support a specific context. A Context, which is relative to the entity, can describe further information about that entity in defining an Asset the context element is utilized to express the spatial boundary. Extending from "contextType" a new spatial type was built adding "gml:envelope" datatype. gml:evelope defines an extent using a pair of positions defining opposite corners, the first is "lower corner" the second one the upper corner". The spatial "context Type" was then used to

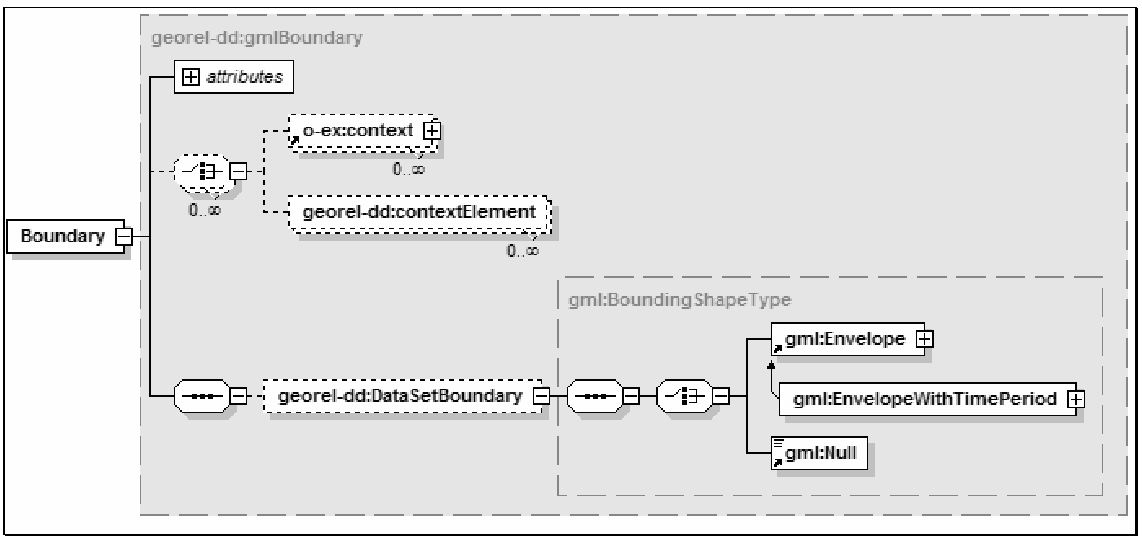

Figure 4-4 the boundary context element

construct a "georel-dd:Boundary" context element within ODRL. (Figure 4-4) illustrates the structure of the GeoDRM boundary context data type. This can now describe bounding boxes on datasets within any entity of the rights expression. With this extension the "gml:envelope" describing the boundaries of certain datasets can be projected in the rights expression. Also Envelopes with Time period can be utilized to describe temporal boundaries (in case of coverages). The fact that Boundary is a GeoREL context element means it can appear in any entity within the other elements that have context as illustrated before in rights expression to enable complex specification of spatial boundaries.

Defining Feature and FeatureType Elements

Another challenge was to build fine-grained right expressions, which requires the ability to specify expressions on specific GML features and feature collections as well as feature Types.

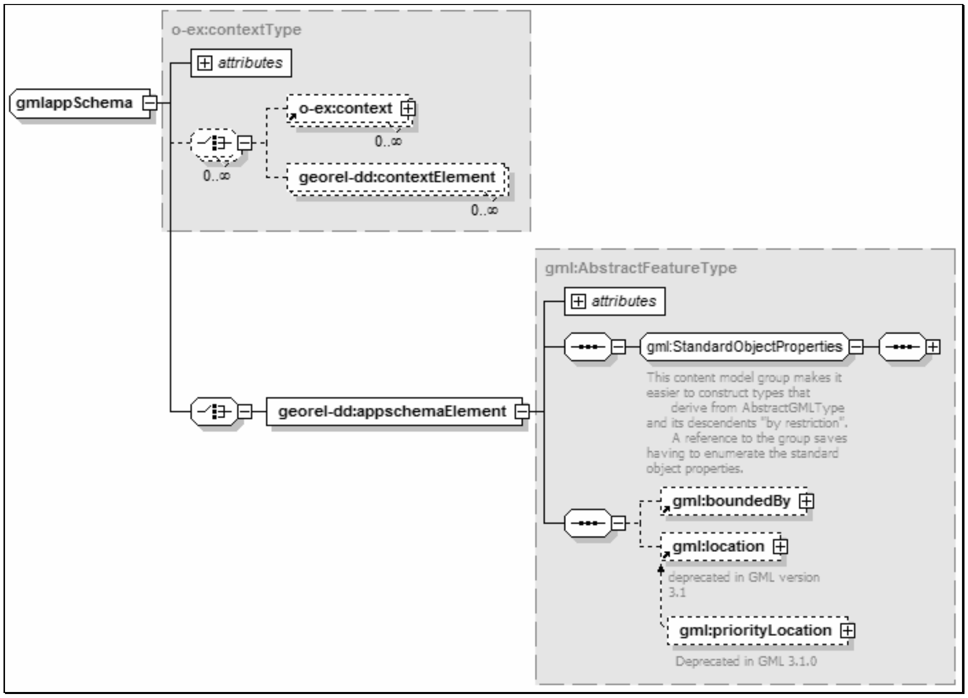

Figure 4-5 appschema element to declare feature level context elements

Figure 4-4 illustrates a new element “georel-dd:gmlappSchema”. The approach followed depends on the XML schema type checking capabilities and the use of any GML application schema (a sample application schema is illustrated in section 4.4). Each vendor releasing his own datasets as GML would have his own GML application schema pertaining to his data model. We need to import the vendor application schema in our developed GeoREL Data dictionary to enable the use of the developed functionality to specify rights on features and feature collections.

First step is building a spatial datatype of type gml:AbstractFeatureType, this spatial type is then used as part of a new GeoREL schema type with extension of an ODRL standard (contextType) which was then used to construct the spatial context element “georel-dd:gmlappSchema”. Second, since the gml:AbstractFeatureType is the basic GML feature model which means that for GML instance of this application schema where features or feature collections are always of type gml:_Feature and gml:_FeatureCollection we can specify Feature types or individual feature instances within the “georel-dd:gmlappSchema” ODRL element. This solution is versatile, since it allows each vendor to import his own GML application schema to the GeoREL data dictionary; hence the extension supplied can describe features in rights objects within the vendor’s specific domain.

Defining spatial permissions

Another spatial extension is “georel-dd:CoordinateOperation” permission (Figure 4-5) which uses the gml:IdentifierType to identify specific GML coordinate operations such as coordinate transformation using the GML vocabulary and semantics. Figure 4-6 below illustrates the permission structure. Other permissions like “ExtractFeature” uses spatial components that have been developed earlier like feature and feature level GML application schema elements to specify which features are allowed for extraction. Section 5.4 provides examples on the uses of these permissions.

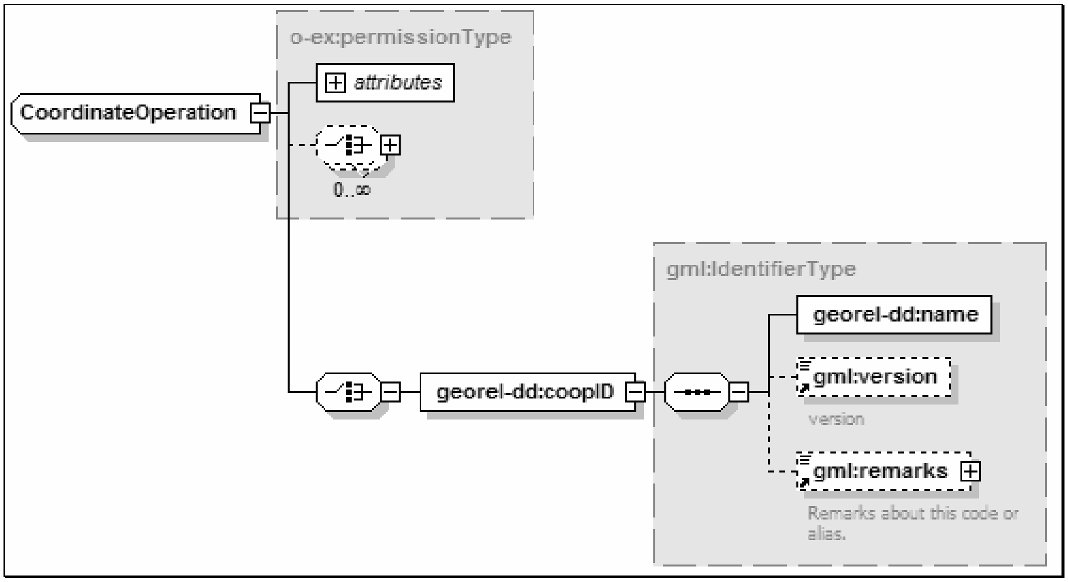

Figure 4-6 the Coordinate operation spatial permission

Defining non-spatial permissions

Other permissions, requirements, and constraints were needed for the proof of concept scenarios which have no spatial properties. An example of these is the permissions is “georel-dd:regrant” (Figure 4-7) which pertains to re-granting certain sets of permissions from a licensee down stream to sub-licensees the elements in the namespace “o-ex” are the standard ODRL child elements inherited by all spatial and non-spatial permissions. For more details on the schema structure refer to the schema and the schema documentation in Appendix A

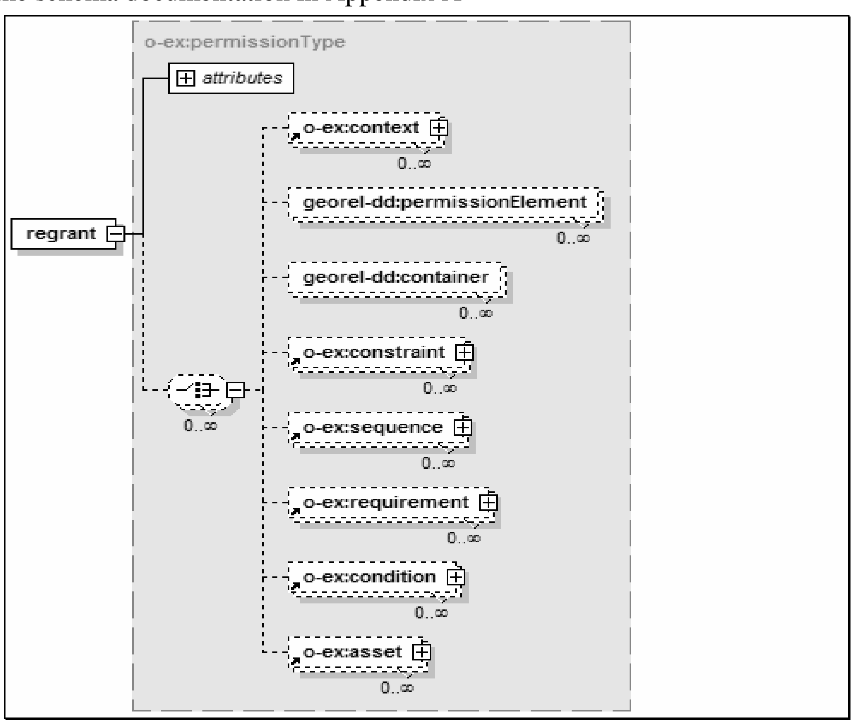

Figure 4-7 the regrant non-spatial permission

4.4. Proof of concept

In this proof of concept, we have built licenses based on the developed Geospatial data dictionary "georel-dd". The licenses revolve around a scenario adopted from Ordnance Survey Print/copy Shop License (OS 2006 BL). Also we have adopted a GML dataset (Matheus, 2005) that is assumed to belong to OS for use within the scenarios.

Due to the lack of GeoDRM technology stack to establish a test-bed the use of the software Altova XMLSpy IDE provided validation for both the developed schema as well as the licenses discussed later in this section. To provide insights on the rights expression using the GeoREL we have the CityModel GML dataset (Figure 4-8).

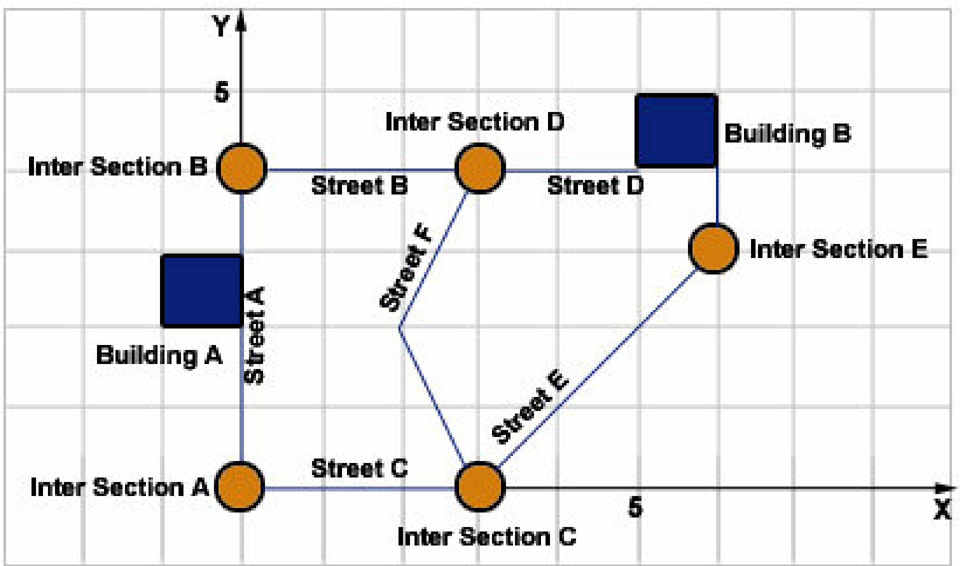

Figure 4-8 CityModel GML Visualization

The GML city model is a GML instance. As previously mentioned each GML instance has a supporting application schema. The application schema of the City Model is illustrated below in Figure 4-9. The application schema defines four types of features, Building, Intersection and Street. Each of these features is substitutable for gml:_Feature. And the fourth type is CityModel which is substitutable for gml:_FeatureCollection. The CityModel schema and the CityModel GML schema instance (the dataset) are attached in (Appendixes E, F). As previously illustrated the Developed GeoREL-DD is ready to express Geolicenses one we import the application schema of the dataset on which the Geolicense is specifying agreements. For the next illustrative examples we use the CityModel application schema which is then imported into the GeoREL-DD as illustrated in (Figure 4-2) to build GeoLicenses for the CityModel dataset used on the three examples illustrated below.

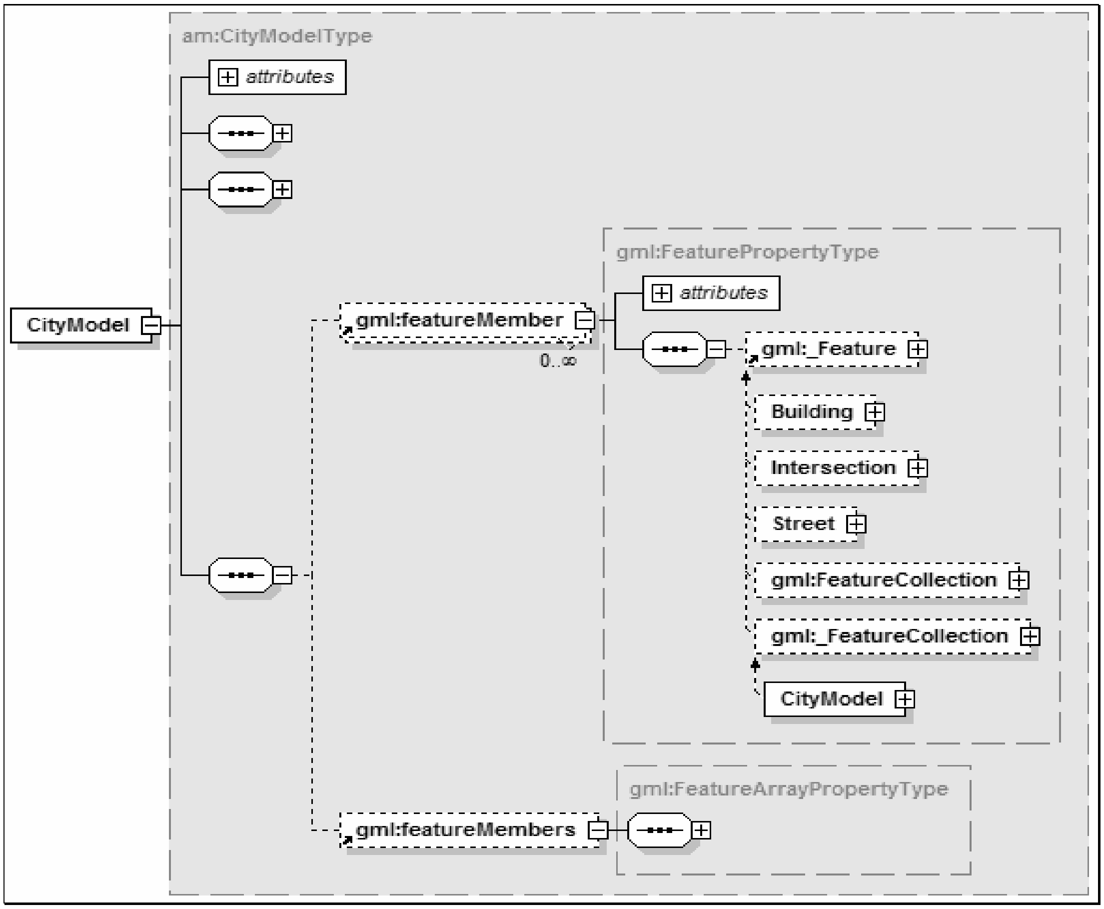

Figure 4-9 City Model Application Schema

4.4.1. OS Print-shop License

In this scenario, we implement the “Ordnance Survey printer/copy shop license” (OS 2006 BL). In this license, OS gives authorization to certified print shops to provide printing services on ordnance survey datasets for varying customer needs. Each shop willing to take part in this program signs a license agreement with OS granting the print-shop the right to print map sheets on certain paper sizes and for each print ordnance survey receives a designated amount of money in royalties. Other terms such as printing watermarks and identifying purpose of customers are in place within the license. The full text of the license can be acquired from (OS 2006 BL).

We make few assumptions about the “OS printer/copy shop license” to pursue building the Geo-license:

- It covers certain datasets (CityModel) to which the print shop is entitled to provide services as described in the license.
- instead of Ordnance survey receiving yearly royalties as stated in the license is running GeoDRM architecture as illustrated in chapter 3, and the compensation service can handle payment of royalties to OS in real-time or near real-time basis.
- The OS license requires the licensed print shop to ask its customers to show the shop staff a valid paper license from OS to use its data. We assume the customer as well has a digital license issued from OS.

In this example we elaborate more on the GeoREL syntax to clarify the concept of the REL. the whole rights object (license) is enclosed between the “o-ex:rights” element pairs as we illustrated before. This constitutes the root element of the GeoREL rights instance as illustrated below.

Declaring the rights object

```
<o-ex:rights Attributes and namespaces used>
  <o-ex:context>
    <o-dd:version>1.0</o-dd:version>
    <o-dd:uid>RightsObject_UniqueIdentifier</o-dd:uid>
    <o-dd:name>OS Standard Printshop License</o-dd:name>
  </o-ex:context>
```

Code Snippet 4-1 Declaring the rights object root element

For the purpose of clarity the o-ex:rights above is missing the namespaces used in the license while they are listed in the license at (Appendix B). The o-ex:context element of the rights expression contains the version of the GeoREL, an o-dd:uid element at which OS places a unique rights object identifier that might pertain to certain numbering in there accounting systems. The purpose is to uniquely identify this license. And at last there is the formal name of the license in “o-dd:name” element.

Defining the Assets in the Geolicense

Below is the first major element defined within this license which is the Asset being licensed. In this case it’s the CityModel dataset. In the unique identification of the Asset we used a DOI schema which was previously mentioned in chapter 3. The first part of the DOI (DOI:10.1036) uniquely identifies OS as an entity. And the second part identifies this particular dataset. However based on the requirements datasets would be defined with geospatial boundaries. Hence we used the GeoREL context element “georel-dd:boundary” to define the gml:Envelope containing the whole dataset. In this manner we have identified a spatial identifier of our asset.

```
<o-ex:asset o-ex:id="a001">
  <o-ex:context>
      <o-dd:uid>DOI:10.1036/CityModel-OSVector/0071369058</o-dd:uid>
      <georel-dd:Boundary>
          <georel-dd:DataSetBoundary>
              <gml:Envelope>
                  <gml:lowerCorner>0 0</gml:lowerCorner>
                  <gml:upperCorner>4 4</gml:upperCorner>
              </gml:Envelope>
          </georel-dd:DataSetBoundary>
      </georel-dd:Boundary>
  </o-ex:context>
</o-ex:asset>
```

Code Snippet 4-2 the Geolicense Asset Element

Defining the Geolicense Agreement

The initial step done was to define the asset covered under the agreement using the “o-ex:idref” property which refers back to the asset declared above. Second was to define an agreement level constraint with the validity period of the agreement as 1 license year within the period defined by the OS license.

```
<o-ex:agreement>
    <o-ex:asset o-ex:idref=”a001”/>
        <o-ex:constraint>
            <o-dd:datetime>
```

```
<o-dd:start>2006-04-01T00:00:00</o-dd:start>
<o-dd:end>2007-03-31T00:00:00</o-dd:end>
</o-dd:datetime>
</o-ex:constraint>
```

Code Snippet 4-3 the agreement validity and which assets are covered

The next step was to define the parties, between which this agreement is established, the first party below is OS. According to our assumptions established earlier OS receives payment of 40% of the transactions costs in royalties. Stemming from IPR concepts a party that has the rightsholder element is special types of party that can receive royalties as it hold rights to the licensed assets. The expression uses an “o-ex:container” element with an “ex-or” attribute which means an exclusive OR. This expression means that one of the two payment methods must be fulfilled either a minimum of 47.5 euros or 40% of each transaction value.

```
<o-ex:party>
  <o-ex:context>
    <o-dd:uid>x500:c=OS</o-dd:uid>
    <o-dd:role>PrimeLicensor</o-dd:role>
  </o-ex:context>
    <o-ex:rightsholder>
      <o-ex:container o-ex:type="in-or">
        <o-dd:percentage>40</o-dd:percentage>
        <o-dd:fixedamount>
          <o-dd:payment>
            <o-dd:amount o-dd:currency="Euro">47.5</o-dd:amount>
          </o-dd:payment>
        </o-dd:fixedamount>
      </o-ex:container>
    </o-ex:rightsholder>
</o-ex:party>
```

Code Snippet 4-4 The first agreement party defined

The second party involved is the Print-shop party which has rights over the assets constituting 60% of the amount of each transaction.

```
<o-ex:party>
  <o-ex:context>
    <o-dd:uid>http://people.net/registry/ITC-PS-9999</o-dd:uid>
      <o-dd:role>PrintShop</o-dd:role>
      <o-dd:name>ITC Certified PrintShop</o-dd:name>
  </o-ex:context>
  <o-ex:rightsholder>
      <o-dd:percentage>60</o-dd:percentage>
  </o-ex:rightsholder>
</o-ex:party>
```

Code Snippet 4-5 the second agreement party defined

After defining the parties we define the permissions, constraints and permission requirements for this particular agreement, which constitute the terms and conditions part of the license. The permission illustrated below starts by giving a “display” right. Then a “print” right, that has two constraints and two requirements. The first constraint “o-dd:printer” defines a trusted printer entity. In this scenario OS grants the shop the licenses to print only on this trusted printer. So that additional printers will always need to be registered with OS. The second constraint is a “papersize” constraint that only permits printing on A6 paper. For this permission to be valid, the requirements must be fulfilled. The requirements are provided with a sequence “o-ex:sequence” to suggest certain ordering in the flow, first the print-shop needs to have it's customers providing an "InternalBusinessUse" license issued to them from OS. Second .28 euros are paid per print as well as a 5% tax.

```
<o-ex:permission>
        <o-dd:display/>
</o-ex:permission >
<o-ex:permission>
    <o-dd:print>
        <o-ex:constraint>
            <o-dd:printer o-ex:id="p001">
              <o-ex:context>
              <o-dd:uid>guid:TrustPrint/4747474742222</o-dd:uid>
            </o-ex:context>
          </o-dd:printer>
            <georel-dd:papersize georel-dd:pSize="A6"/>
       </o-ex:constraint>
       <o-ex:requirement>
         <o-ex:sequence o-ex:order="total">
              <o-ex:seq-item o-ex:number="1">
              <georel-dd:checkuserlicensetype>
              <georel-dd:InternalBusinessUse/>
                 </georel-dd:checkuserlicensetype>
              </o-ex:seq-item>
          <o-ex:seq-item o-ex:number="2">
         <o-dd:peruse>
            <o-dd:payment>
              <o-dd:amount o-dd:currency="Euro">.28</o-dd:amount>
              <o-dd:taxpercent o-dd:code="VAT">5</o-dd:taxpercent>
          </o-dd:payment>
          </o-dd:peruse>
         </o-ex:seq-item>
       </o-ex:sequence>
    </o-ex:requirement>
    </o-dd:print>
 </o-ex:permission>
```

Code Snippet 4-6 Print-shop agreement permission

In this example we have illustrated how to model a license to the Developed GeoREL and have provided illustration to many aspects including and the city model vector dataset is represented with spatial properties in the Geolicense. The details of the Geolicense are attached as Appendix B.

4.4.2. Feature level license

In the previous example, we illustrated how the print/copy shop license was presented; at this section, we illustrate a complementary license to the previous example. Based on the assumption made earlier on, the print/shop customer needs to provide the print-shop with a valid OS license OS can now issues customers digital licenses specifying areas of coverage and certain features or dataset layers. These licenses can be presented by the customer to the print-shop online or offline to authorize the requested prints for each customer.

Defining the Assets in the Geolicense

The asset element below follows (code snippet 4-7) a similar method to define the CityModel dataset boundaries. However for this license the OS customer has rights only over feature types of StreetType and IntersectionType features. Using the method defined in section 4.3 to express rights on the feature level we used the developed "georel-dd:gmlfeature" element to describe the two featureTypes as illustrated below, The <georel-dd:appschemaElement xsi:type="am:StreetType"/> element defines "am:streetType" which all the streets in the CityModel dataset are part of.

```
<o-ex:asset o-ex:id="a001">
    <o-ex:context>
        <o-dd:uid>DOI:10.1523/OSVector.3721-05.2006</o-dd:uid>
            <georel-dd:Boundary>
                <georel-dd:DataSetBoundary>
                    <gml:Envelope>
                        <gml:lowerCorner>0 0</gml:lowerCorner>
                        <gml:upperCorner>4 4</gml:upperCorner>
                    </gml:Envelope>
            </georel-dd:DataSetBoundary>
          </georel-dd:Boundary>
          <georel-dd:gmlfeature>
                <georel-dd:appschemaElement xsi:type="am:StreetType"/>
          </georel-dd:gmlfeature>
                <georel-dd:gmlfeature>
                    <georel-dd:appschemaElement xsi:type="am:IntersectionType"/>
                </georel-dd:gmlfeature>
    </o-ex:context>
</o-ex:asset>
```

Code Snippet 4-7 The Geolicense asset element

Defining the Geolicense Agreement

In this sections we don’t focus on the agreement element as it’s following the same method in the previous example, thus we focus on the permissions, constraints and the requirements. In the permission blow we grant permission over the previously defined assets with this statement <o-ex:asset o-ex:idref="a001"/> . We then define spatial permissions such as “extractFeature” and “CoordinateOperation”. Since this license can as well be used by the OS customer to request printing at a certified print shop the “print” permission is described as the previous example, however in this example the we describe a constraint on the feature with the feature “ID=S1” in the CityModel instance. By using the same construct to define the assets above <georel-dd:appschemaElement xsi:type="am:StreetType" gml:id="S1"/> and adding the feature ID at the element property of type gml:id we specified a specific feature within the streetType features by using the feature ID. This license requires the prepayment of the specified amount once a year in the validity of the license. For the detailed license instance refer to (Appendix D)

```
<o-ex:permission>
    <o-ex:asset o-ex:idref="a001"/>
        <georel-dd:coordoperation o-ex:id="c001">
            <georel-dd:coopID>
                <gml:name>CTrans1</gml:name>
            </georel-dd:coopID>
        </georel-dd:coordoperation>
        <georel-dd:extractfeature o-ex:id="e001"/>
        <georel-dd:spatialoperator o-ex:id="s001"/>
        <o-dd:print o-ex:id="p001">
            <o-ex:constraint>
                <o-ex:context>
                    <georel-dd:gmlfeature>
                        <georel-dd:appschemaElement xsi:type="am:StreetType" gml:id="S1"/>
                    </georel-dd:gmlfeature>
                </o-ex:context>
                <georel-dd:papersize georel-dd:pSize="A3"/>
                <georel-dd:printresolution georel-dd:pRes="All"/>
            </o-ex:constraint>
        </o-dd:print>
        <o-dd:duplicate/>
        <o-dd:display o-ex:id="d001"/>
        <o-dd:watermark/>
        <o-ex:requirement>
            <o-dd:prepay>
```

```
                <o-dd:payment>
                    <o-dd:amount o-dd:currency="Euro">3500</o-dd:amount>
                    <o-dd:taxpercent o-dd:code="VAT">5</o-dd:taxpercent>
                </o-dd:payment>
            </o-dd:prepay>
        </o-ex:requirement>
    </o-ex:permission>
```

Code Snippet 4-8 The Geolicense spatial permissions

4.4.3. Print-shop Preview GeoLicense

The last example we a simple preview license (Appendix C) where the licensee can re-grant the rights to others for the purpose of previewing the same dataset. Explained below is the developed "georel-dd" regrant permission. The "o-dd:transferrPerm" element allows the licensee to "re-grant" the permissions listed in three distinct moods define by the "o-dd:downstream" property. The value" equal" for this property allow for the same permissions only to be transferred (i.e. display and print must be granted) while a if the "o-dd:downstream" attribute had the value "less" then the permissions re-granted to sublicensees must be less than the permissions listed in the original license. If the attribute had the value "notgreater" then it means not less than or equal to the permissions listed in the license. According to this license, the licensee can give other users the permissions to preview the CityModel dataset, and it can be printed twice on A4 paper, with a watermark on the background.

```
<o-ex:permission>
        <georel-dd:regrant>
                <o-dd:transferPerm o-dd:downstream="equal">
                        <o-dd:display o-ex:idref="p001"/>
                        <o-dd:print o-ex:idref="p002"/>
                </o-dd:transferPerm>
        </georel-dd:regrant>
</o-ex:permission>
```

Code Snippet 4-9 The Geolicense spatial permissions

4.5. Conclusions

In this chapter, we have provided a proof of concept for the GeoREL. The examples have shown that the approach developed can accommodate the major requirements of geospatial rights expression. We have demonstrated the ability to specify boundaries or licenses, as well as spatial and non-spatial permissions. In addition, the capability to express features and feature collection level permissions was demonstrated. Using Ordnance Survey license scenario we illustrated that ODRL and RELs in general provide a mechanisms to express contractual agreements. In chapter 3, we have listed five general requirements of the GeoREL. One requirement that is the composite licenses we addressed that is out of the scope of this research. The four remaining requirements and a brief description of how we resolved them is enumerated below

1. Rights Granularity: through the element <georel-dd:appSchemaElemet> we were able to specify rights on various granularities. On a single feature level, and feature collection as well as feature types. examples of it's use is illustrated in section 4.4.2
2. Spatial extent of licenses: we have implemented a <georel-dd:Boundary> element and illustrated how this can be used to express spatial extents of licenses. Examples of it's use are illustrated in section 4.4.1 through 4.4.3
3. Types of Permissions: we have implemented various spatial permissions as illustrated in figure 4-3. examples of there use are illustrated in section 4.4.2

4. Administration rights: for this particular proof of concept we have implemented one administration right which is the <georel-dd:regrant> to enable regranting of the rights by licensors to sublicenses and demonstrated an example of its use in section 4.4.3. In conjunction with the standard ODRL element <o-dd:downstream> regrant can be used to control the flow of IPR downstream in the value chain in the moods illustrated in section 4.4.3.

The Geospatial extension of RELs means that a REL maintains the same inherent capabilities in describing contractual agreements while providing the facilities essential to express contracts over geospatial assets (Geolicenses). In section 1.2 we addressed the research context. The above requierements listed satisify the frame of the research context main aspects regarding specifying assets with the geolicense as part from a continous larger whole such as geospatial datasets (i.e. as opposed to discreet assets like books). As well as the ability to specify, clear terms and conditions on the geospatial assets, which are inherently non-discreet.

This approach extending ODRL can be used to extend other RELs. In chapter 3, we have listed five general requirements of the GeoREL.

In the next chapter, we address the conclusions, recommendations, and future work stemming from this research

5. Conclusions and Recommendations

5.1. Introduction

The main objective of this research was to develop an approach for the expression of digital licenses on GML datasets. To achieve this objective we first needed further understanding of GeoDRM scope and the technologies that support the GeoDRM framework. Since GeoDRM is a novel topic we have followed top down approach to the problem by defining GeoDRM. We proposed a GeoDRM reference architecture, developed a GeoDRM information model and finally we proposed an approach for the expression of digital licenses for GML.

This research was conducted in three phases. The goal of the first phase was to understand GeoDRM scope and technology as an initial step to position this research within the larger picture of GeoDRM. We have studied definitions of DRM and the general components of DRM. During this study, it was found that DRM has technical and legal frameworks which are integral part of a DRM policy. We then mapped the findings from the general DRM framework to GeoDRM; we then examined the current licensing in the geospatial domain as the dominant mode for dissemination of IPR. We finally concluded this phase by defining GeoDRM spectrum and further narrowed down the scope of this research within the digital licensing as an integral part of GeoDRM.

In the second phase we examined relevant DRM technologies that are employed for digital licensing. The findings were then mapped into the GeoDRM reference architecture which we proposed in chapter 3. We then established the GeoDRM information model and elaborated on each of the elements of the information model in section 3.4. A general set of requirements for the digital licensing of GML datasets were then identified 3.5 and the geolicense model was introduced in section 3.6. This model adopts the relevant IPR semantics from the ODRL (open digital rights language).

In the last phase we designed the ODRL extension to build a GeoREL that is capable of expressing geolicenses and illustrated the process used to extend the ODRL REL. a proof of concept was conducted using scenarios derived from Ordnance Survey “Print/Copy shop license” to illustrate the use of the proposed GeoREL.

5.2. Achieved results against Research outline

In this section we review the achieved results of this research against the objectives and research questions stated in chapter 1 as the basis for the general conclusions. Recommendations and future research are then presented in section 5.3.1 5.3.2 respectively.

- **Define the elements of GeoDRM framework**
  1. *What is DRM and how is it different from seemingly similar fields like access control?*

     It was found that DRM is for the management of rights over digital assets (see section 2.3). An asset is defined in the Webster dictionary as “an item of value owned”. In the realm of Service Oriented Architecture (SOA), an organization can own the rights to a service rather than digital content. Other researchers asserted a general similarity between DRM and access control, however we defined this similarity to be rather from a technical perspective. Access control defines policies that govern parties that are allowed to access assets. DRM is however fundamentally different in that it stems from intellectual property rights (IPR) dealing with the ownership of the assets. Digital licenses in DRM are legal contracts governing the dissemination of IPR. We concluded that DRM always consists of a technical aspect and a policy aspect that is manifested in the form of legal contractual agreements that are further under effect by the statutory IPR laws (see section 2.4). It is therefore important to realize that DRM systems are combination of technical and legal measures employed to control the dissemination of IPR.

  2. *How are Geospatial Intellectual property rights currently being disseminated?*

     In section 2.4 we illustrated the formal relationship between IPR, Laws and contractual law (licensing). Important assertions were made regarding the relationship which assisted us in better understanding the role of DRM. We then mapped our findings to the geospatial community and concluded that licensing is the common means of dissemination of IPR in the geospatial domain community. However the complexity of defining licensed rights stems from the fact that licensing rights are a reconciliation of two often contradicting rulings,

     - The statutory rights granted by the IPR laws (e.g. copyrights)
     - And the permissions on assets granted as licensed rights in licenses.

     We have concluded that licensed rights could grant narrower or wider (copyleft) set of rights to licensees than originally permitted by copyrights laws. And that licensing of geospatial content doesn’t relinquish the protection provided by IPR laws unless stated in the licenses.

  3. *Why GeoDRM is needed in today’s geospatial data sharing environments?*

     GeoDRM is driven by market needs, we have looked briefly into forces leading to the emergence of GeoDRM like the vision for a geospatial market place, INSPIRE and ordnance survey’s online business models. From section 2.4 and 2.5 we concluded that the need stems from the widespread use of web-based geospatial services and the effects of digital environments on data sharing where geospatial providers face the need to control the dissemination of IPR downstream in the value chain.

4. *What is the definition and scope of GeoDRM?*
   - GeoDRM can mean different set of technologies in different situations (see section 2.5). Ordnance survey uses click-thorough, and OGC implemented click-through mechanisms for the Web map server.
   - Digital licensing as addressed in this thesis is a form of GeoDRM
   - Watermarking, encryption, and enforced contracts are all degrees of GeoDRM that can be combined together with legal frameworks to form IPR dissemination policies.
   - It's not practical to define GeoDRM as a single technology. Rather, its better be defined through the GeoDRM spectrum where new technologies are added to the spectrum as it emerges from user needs.
   - GeoDRM can be defined as a set of technologies and legal frameworks that are fit to a certain organizational need, forming a GeoDRM policy for enabling rights managed geospatial networks (e.g. SDIs) where all rights over geospatial assets are specified by the licensors.
   - We have identified the role of trust in GeoDRM. As parties involved in geospatial sharing, transactions become recognized and agreements are guaranteed to be expressed and honored establishing trust between entities serves as an important role in ensuring the success of the system.

- **To develop a high level reference architecture for GeoDRM digital licensing**

5. *How digital licensing of assets is managed on web environments?*

   In section 3.2 we addressed the DRM reference architecture. We asserted that the architecture is content centric as well as it doesn't illustrate more details on what are the services needed for management of digital license instances. The DRM licensing infrastructure was then presented as the latest development in management of digital licensing that focuses on licensing of assets as defined in this thesis (i.e., content and services). We also illustrated the array of services provided and there roles.

6. *What are the components of the GeoDRM reference architecture?*

   In section 3.3 we introduced the GeoDRM architecture which is composed of five major services. These are Negotiation service, digital rights service, compensation service, service level agreement service and the administrative GeoDRM service. The GeoDRM gateway handles the delegation of requests to services. In three UML sequence diagrams we illustrated three main scenarios involving the architecture. The goal was to illustrate the sequence of interaction between major services. The scenarios cover the main activities in web access of geospatial data. The scenarios are acquiring license first and dataset later, acquire dataset first and license later, acquire license and dataset combined. This architecture is a high level architecture for GeoDRM digital licensing.

- **Define a General GeoDRM Information model.**

7. *How can we develop a GeoDRM reference information model and what are the components of the GeoDRM reference information model?*

In section 3.4 we studied the major components of a DRM information model. We have not been able to find a particular DRM information model since such model is somehow arbitrary and domain dependant. Figure 3-9 illustrates the UML model of the GeoDRM information model, and subsequent sections elaborated on the meaning and role of each of the element in the model. In this research we have established the information model and we asserted that RELs are the means of building instances of this information model. In this work we only addressed the expression of rights over spatial assets.

- **To identify an appropriate method to describe contractual agreements for licensing of geospatial digital content via a rights expression language and develop an extension to an existing licensing standard as a proof of concept.**

8. *What are the general requirements of geospatial rights expression on GML datasets?*

To answer this question we put forward a hypothesis based on our understanding of the GeoDRM architecture and on how licenses are being used. Combining this understanding with the information drawn from the GeoDRM information model and the granular nature of GML (feature level, feature collections, spatial and non spatial properties of features), we identified a general set of high level requirements that would guide a development of a proof of concept to validate the proposed rights expression approach.

9. *How do we accommodate the above requirements in existing Rights expression languages?*

- To answer this question a novel approach was proposed to extend existing REL with Geospatial capabilities. In section 3.6 we concluded on the GeoDRM information model and the requirements with the geolicense model. One of the finding of this research is that modelling a digital license needs to be done inline with a certain rights expression language. The reason for this particular point is that RELs provide semantics and vocabulary for expression IPR concepts. Hence utilizing the basic information model of the ODRL (open digital rights language) we proposed a geolicense model which is illustrated in figure 3-12. The geolicense model uses ODRL semantics for expressing the relations between the assets, agreements, parties, and permissions, while the model is extended with spatial permissions and spatial constraints, as well as spatial properties to assist in expressing the assets.
- The approach uses The GML schema to build spatial data types within the ODRL language which enabled the expression of spatial properties within the geolicense.
- ODRL consists of a data dictionary schema and a rights expression schema. A new spatial data dictionary has been developed to accommodate the requirements of the Geolicense as sown in chapter 4.

- The approaches have been validated using, Altova XML spy due to lack of GeoDRM technology implementations. License scenarios emulating the Ordnance survey Print/shop license have been modeled assuming OS is issuing digital licenses to its customers. The functionality of the developed schema in expression of geolicenses on GML datasets has been demonstrated.

5.3. Recommendations and Future Work

Some recommendations are drawn from this research regarding GeoDRM digital licensing and GeoDRM in general.

5.3.1. General research recommendations

- Harmonized licensing frameworks are an essential step towards a GeoDRM policy in GI organizations. This stems from our finding in DRM related fields, INSPIRE initiative seeks to develop harmonized licensing frameworks as an initial step towards employing click-through licensing mechanisms for the data themes covered within the initiative.
- Due to the time limitations and the problems encountered to conduct field work we haven't been able to conduct an active requirements analysis for a certain organizational situation. However it is recommended that a detailed study be carried out across various organizations (ordnance survey, Dutch cadastre, etc...) and geospatial data sharing settings (e.g. INSPIRE, NRW, GeoConnections, etc...) to gather a wider set of requirements regarding a wide range of stakeholder needs.
- It is recommended that modelling of geolicenses be done with respect to a certain rights expression language to benefit from the inherent IPR semantics within the rights expression language.
- The usage of GML schema into the developed REL schema provided efficient means for building spatial data types. Hence this approach is recommended when considering the extension of RELs to enable expressing geolicenses.

5.3.2. Future Work

- GeoDRM has legal and technology 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.
- Study how digital licensing and other GeoDRM technologies will affect business models of GI organizations.
- Study how to build business models that leverage GeoDRM technologies to fully benefit from online web-based geospatial data sharing.
- (Francis Harvey, 2003; Francis Harvey *et al.*, 2004) stresses 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 on GeoDRM's ability to unambiguously define liabilities and duties of parties involved in data sharing.
- Each of the elements within the GeoDRM information model needs further study. For example:

  - To derive a full fledged geospatial rights model further analysis is needed across various organizations to define the set of rights within each of the categories (render rights, transport rights, derivative work rights and administrative rights).
  - Methods for Unique identification information needs to be researched this includes; unique identification of assets (individual datasets and services), parties and right holders, as well as digital license instances.
  - Trust information is an important aspect of research. Identifying what information constitutes the GeoDRM trust model is an essential research step. Also which elements and information needs to be shared about the parties to increase trust in the GeoDRM framework (e.g. Quality, provenance of transactions for participating parties etc…)
  - Asset protection information and techniques are another area of research. Watermarking, fingerprinting and encryption can be combined with various measures of protection to serve a myriad of business models. Watermarking of geospatial datasets is a new area of research specially watermarking of vector datasets which so far have received less attention than raster datasets watermarking.

- This research focused on the expression of digital licenses using RELs on GML datasets, no further research was conducted on the enforcement of rights. Further study on enforcement of geolicenses is needed.

- This research focused only on GML vector data. Further research is needed to provide a GeoDRM capability on Map data and coverages as well as other data formats (e.g. shape files).

- GML is mainly used as a mechanism to encode geospatial datasets for exchange. How do we maintain the mapping between GML datasets and their respective licenses after they are imported into a client's database? Many questions would arise in this area of research that would also have profound effects on persistent enforcement of digital licenses.

- Since digital licenses contain information about the spatial assets (e.g. boundaries) could these licenses be used as service access tickets? (e.g. do we need a "GetFeature" permissions on a WFS or is it sufficient to send the license which constitutes an implicit "GetFeature" Request) this allows users to send licenses to services which would then release datasets accordingly. licenses would also be used to enforce the rights on the client machine.

- Extending current metadata standards and the OGC CSW service to accommodate the rights metadata needed as discussed in section 3.4.1.4. Also establishing a GeoDRM product catalogue to enable expression of generalized licensing frameworks on certain assets as products which enable the negotiation service to negotiate licenses on assets based on these generalized licensing schemas.

- In section 3.5 we addressed the need to construct semantically correct licenses (or permissions decisions) out of a set of heterogeneous licenses over a certain asset or part of an asset when combining datasets. We stated that resolving this issue is outside the scope of this research. We believe that Ontologies and Rules (Web Ontology Language, OWL, and Semantic Web Rule Language SWRL) will enable us to provide reasoning capabilities to resolve conflicts in a stack of licenses.

- Research and development in building the GeoDRM architecture services is an essential step to enable testing of the technical work and the theoretical concepts developed in GeoDRM research.

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Appendix (A): The Developed GeoREL Schema

- **The schema file supplied on CD with this thesis is GeoREL-DD.xsd**

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2006 sp1 U (http://www.altova.com) by Mohamed Bishr (EMBRACE) -->
<!-- Mohamed Bishr All Rights Reserved 2006-3- 3-->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:gml="http://www.opengis.net/gml" xmlns:o-
ex="http://odrl.net/1.1/ODRL-EX" xmlns:o-dd="http://odrl.net/1.1/ODRL-DD" xmlns:am="http://www.in.tum.de/am"
xmlns:georel-dd="http://example.net/georel-dd" targetNamespace="http://example.net/georel-dd"
elementFormDefault="qualified" attributeFormDefault="qualified" version="1.1">
	<xsd:annotation>
		<xsd:documentation>
			<version>1.0.0</version>
			<copyright>Copyright (c) 2005-2006 Mohamed Bishr, ITC, All Rights
Reserved</copyright>
		</xsd:documentation>
	</xsd:annotation>
	<!--List Of Imports-->
	<xsd:import namespace="http://odrl.net/1.1/ODRL-EX" schemaLocation="http://www.odrl.net/1.1/ODRL-EX-
11.xsd"/>
	<xsd:import namespace="http://odrl.net/1.1/ODRL-DD" schemaLocation="http://www.odrl.net/1.1/ODRL-DD-
11.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\feature.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\coordinateReferenceSystems.xsd"/>
	<xsd:import namespace="http://www.in.tum.de/am" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\CityModel\CityModel.xsd"/>
	<!--GREL Schema-->
	<!--declare new GeoREL datatypes-->
	<!--gml boundary to define the dataset boundaries in the context element of any entity specially asset entity-->
	<xsd:complexType name="gmlBoundary">
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:sequence>
					<xsd:element name="DataSetBoundary"
type="gml:BoundingShapeType" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!-- Defining this datatype makes it possible to specifiy application schema features in a rights expression n the
context extity like in an asset element for exmaple-->
	<xsd:complexType name="gmlappSchema">
		<xsd:annotation>
			<xsd:documentation>
datatype is used to construct a context element of Type gml:AbstractFeatureType.
	</xsd:documentation>
		</xsd:annotation>
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:choice>
					<xsd:element name="appschemaElement"
type="gml:AbstractFeatureType"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define a datatype to be used to specify Coordinateoperation using a gml Type to make it possible to specify
same operation defined in GML-->
```

```
<xsd:complexType name="CoordinateOperation">
	<xsd:complexContent>
		<xsd:extension base="o-ex:permissionType">
			<xsd:choice>
				<xsd:element name="coopID" type="gml:IdentifierType"/>
			</xsd:choice>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
<!--define a datatype to be used to specify new requierements-->
<xsd:complexType name="customerlicense">
	<xsd:complexContent>
		<xsd:extension base="o-ex:requirementType">
			<xsd:choice>
				<xsd:element name="InternalBusinessUse" type="xsd:string"
minOccurs="0"/>
				<xsd:element name="other" type="xsd:string" minOccurs="0"/>
			</xsd:choice>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
<!--define new datatypes to be used for a specific variation of print constraints-->
<xsd:complexType name="printResType">
	<xsd:complexContent>
		<xsd:extension base="o-ex:constraintType">
			<xsd:attribute name="pRes" default="200dpi">
				<xsd:simpleType>
					<xsd:restriction base="xsd:NMTOKEN">
						<xsd:enumeration value="200dpi"/>
						<xsd:enumeration value="300dpi"/>
						<xsd:enumeration value="600dpi"/>
						<xsd:enumeration value="All"/>
					</xsd:restriction>
				</xsd:simpleType>
			</xsd:attribute>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
<xsd:complexType name="printPaperType">
	<xsd:complexContent>
		<xsd:extension base="o-ex:constraintType">
			<xsd:attribute name="pSize" default="A4">
				<xsd:simpleType>
					<xsd:restriction base="xsd:NMTOKEN">
						<xsd:enumeration value="A6"/>
						<xsd:enumeration value="A5"/>
						<xsd:enumeration value="A4"/>
						<xsd:enumeration value="A3"/>
						<xsd:enumeration value="A2"/>
						<xsd:enumeration value="A1"/>
						<xsd:enumeration value="A0"/>
					</xsd:restriction>
				</xsd:simpleType>
			</xsd:attribute>
		</xsd:extension>
	</xsd:complexContent>
</xsd:complexType>
<!-- Declare New Requirement elements-->
<xsd:element name="checkuserlicensetype" type="georel-dd:customerlicense" substitutionGroup="o-
ex:requirementElement"/>
<!-- Declare New Permession elements-->
<!-- A permission to grant other permession as opposed to sell, move etc... -->
<xsd:element name="regrant" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
<xsd:element name="coordoperation" type="georel-dd:CoordinateOperation" substitutionGroup="o-
ex:permissionElement">
	<xsd:annotation>
```

```
                              <xsd:documentation>this element describes a coordinate operation permissions which uses gml:identifierType to describe the operation name equivalent to the GML application schema</xsd:documentation>
                        </xsd:annotation>
            </xsd:element>
            <xsd:element name="geometryconversion" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="qualitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="quantitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="newgeometry" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="spatialoperator" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="spatialrelation" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <xsd:element name="extractfeature" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
            <!-- Declare New Context elements-->
            <!-- to decalre geometric boundaries within a given context specially in the asset element representing whole datasets-->
            <xsd:element name="Boundary" type="georel-dd:gmlBoundary" substitutionGroup="o-ex:contextElement"/>
            <xsd:element name="gmlfeature" type="georel-dd:gmlappSchema" substitutionGroup="o-ex:contextElement"/>
            <!-- Declare new Constraint Elemnts-->
            <xsd:element name="printresolution" type="georel-dd:printResType" substitutionGroup="o-ex:constraintElement"/>
            <xsd:element name="papersize" type="georel-dd:printPaperType" substitutionGroup="o-ex:constraintElement"/>
            <!-- create new condition elements-->
            <!-- <xsd:element name="commercial " type="georel-dd:CoordinateOperation" substitutionGroup="o-ex:permissionElement"/>-->
</xsd:schema>
```

Data Dictionary Semantics

DD vocabulary	Semantics
checkuserlicensetype	This element is used as a requirement where users need to apply a valid license to the print-shop to request print services.
regrant	This is a permissions to grant certain permissions as specified within it for other sub-licensees
Coordoperation	This is a permission to perform a certain coordinate operation (e.g. coordinate transformation) as named using the gml:name property of this element.
Geometryconversion	Is a permissions to generalize for example from polygon to centerline in a road feature db
Qualitativeoperations	Permission element to do qualitative operations, these are mostly topological, like give me all features on the right side of this road segment
Quantitativeoperations	Permission element to do quantitative operation and are operations that involve computation, buffering, intersect
extractfeature	Permission element to extract features from a certain dataset
Spatialrelation	Is a qualitative operation to allow querying based on topological relations
Spatialoperator	Permission element to do spatial operators which are those spatial operations that generate a new feature
Boundary	Is a context Element to specify the boundaries of a dataset.
gmlfeature	Is a context element to specify features, Feature Type, and feature collection level elements

Printerresolution	An element to specify the resolution of printing.
Papersize	An element to specify the size of paper

Appendix (B): License Scenario 4.4.1 XML instance

- **The schema file supplied on CD with this thesis is PrintShop.xml**


```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2006 sp1 U (http://www.altova.com) by Mohamed Bishr (EMBRACE) -->
<!-- Mohamed Bishr All Rights Reserved 2006-3- 3-->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:gml="http://www.opengis.net/gml" xmlns:o-
ex="http://odrl.net/1.1/ODRL-EX" xmlns:o-dd="http://odrl.net/1.1/ODRL-DD" xmlns:am="http://www.in.tum.de/am"
xmlns:georel-dd="http://example.net/georel-dd" targetNamespace="http://example.net/georel-dd"
elementFormDefault="qualified" attributeFormDefault="qualified" version="1.1">
	<xsd:annotation>
		<xsd:documentation>
			<version>1.0.0</version>
			<copyright>Copyright (c) 2005-2006 Mohamed Bishr, ITC, All Rights
Reserved</copyright>
		</xsd:documentation>
	</xsd:annotation>
	<!--List Of Imports-->
	<xsd:import namespace="http://odrl.net/1.1/ODRL-EX" schemaLocation="http://www.odrl.net/1.1/ODRL-EX-
11.xsd"/>
	<xsd:import namespace="http://odrl.net/1.1/ODRL-DD" schemaLocation="http://www.odrl.net/1.1/ODRL-DD-
11.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\feature.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\coordinateReferenceSystems.xsd"/>
	<xsd:import namespace="http://www.in.tum.de/am" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\CityModel\CityModel.xsd"/>
	<!--GREL Schema-->
	<!--declare new GeoREL datatypes-->
	<!--gml boundary to define the dataset boundaries in the context element of any entity specially asset entity-->
	<xsd:complexType name="gmlBoundary">
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:sequence>
					<xsd:element name="DataSetBoundary"
type="gml:BoundingShapeType" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!-- Defining this datatype makes it possible to specifiy application schema features in a rights expression n the
context extity like in an asset element for exmaple-->
	<xsd:complexType name="gmlappSchema">
		<xsd:annotation>
			<xsd:documentation>
datatype is used to construct a context element of Type gml:AbstractFeatureType.
	</xsd:documentation>
		</xsd:annotation>
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:choice>
					<xsd:element name="appschemaElement"
type="gml:AbstractFeatureType"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define a datatype to be used to specify Coordinateoperation using a gml Type to make it possible to specify
same operation defined in GML-->
```

```
		<xsd:complexType name="CoordinateOperation">
			<xsd:complexContent>
				<xsd:extension base="o-ex:permissionType">
					<xsd:choice>
						<xsd:element name="coopID" type="gml:IdentifierType"/>
					</xsd:choice>
				</xsd:extension>
			</xsd:complexContent>
		</xsd:complexType>
		<!--define a datatype to be used to specify new requierements-->
		<xsd:complexType name="customerlicense">
			<xsd:complexContent>
				<xsd:extension base="o-ex:requirementType">
					<xsd:choice>
						<xsd:element name="InternalBusinessUse" type="xsd:string"
minOccurs="0"/>
						<xsd:element name="other" type="xsd:string" minOccurs="0"/>
					</xsd:choice>
				</xsd:extension>
			</xsd:complexContent>
		</xsd:complexType>
		<!--define new datatypes to be used for a specific variation of print constraints-->
		<xsd:complexType name="printResType">
			<xsd:complexContent>
				<xsd:extension base="o-ex:constraintType">
					<xsd:attribute name="pRes" default="200dpi">
						<xsd:simpleType>
							<xsd:restriction base="xsd:NMTOKEN">
								<xsd:enumeration value="200dpi"/>
								<xsd:enumeration value="300dpi"/>
								<xsd:enumeration value="600dpi"/>
								<xsd:enumeration value="All"/>
							</xsd:restriction>
						</xsd:simpleType>
					</xsd:attribute>
				</xsd:extension>
			</xsd:complexContent>
		</xsd:complexType>
		<xsd:complexType name="printPaperType">
			<xsd:complexContent>
				<xsd:extension base="o-ex:constraintType">
					<xsd:attribute name="pSize" default="A4">
						<xsd:simpleType>
							<xsd:restriction base="xsd:NMTOKEN">
								<xsd:enumeration value="A6"/>
								<xsd:enumeration value="A5"/>
								<xsd:enumeration value="A4"/>
								<xsd:enumeration value="A3"/>
								<xsd:enumeration value="A2"/>
								<xsd:enumeration value="A1"/>
								<xsd:enumeration value="A0"/>
							</xsd:restriction>
						</xsd:simpleType>
					</xsd:attribute>
				</xsd:extension>
			</xsd:complexContent>
		</xsd:complexType>
		<!-- Declare New Requirement elements-->
		<xsd:element name="checkuserlicensetype" type="georel-dd:customerlicense" substitutionGroup="o-
ex:requirementElement"/>
		<!-- Declare New Permession elements-->
		<!-- A permission to grant other permession as opposed to sell, move etc... -->
		<xsd:element name="regrant" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="coordoperation" type="georel-dd:CoordinateOperation" substitutionGroup="o-
ex:permissionElement">
			<xsd:annotation>
```

```
                                        <xsd:documentation>this element describes a coordinate operation permissions which uses
gml:identifierType to describe the operation name equivalent to the GML application schema</xsd:documentation>
                                </xsd:annotation>
                </xsd:element>
                <xsd:element name="geometryconversion" type="o-ex:permissionType" substitutionGroup="o-
ex:permissionElement"/>
                <xsd:element name="qualitativeoperations" type="o-ex:permissionType" substitutionGroup="o-
ex:permissionElement"/>
                <xsd:element name="quantitativeoperations" type="o-ex:permissionType" substitutionGroup="o-
ex:permissionElement"/>
                <xsd:element name="newgeometry" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
                <xsd:element name="spatialoperator" type="o-ex:permissionType" substitutionGroup="o-
ex:permissionElement"/>
                <xsd:element name="spatialrelation" type="o-ex:permissionType" substitutionGroup="o-
ex:permissionElement"/>
                <xsd:element name="extractfeature" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
                <!-- Declare New Context elements-->
                <!-- to decalre geometric boundaries within a given context specially in the asset element representing whole
datasets-->
                <xsd:element name="Boundary" type="georel-dd:gmlBoundary" substitutionGroup="o-ex:contextElement"/>
                <xsd:element name="gmlfeature" type="georel-dd:gmlappSchema" substitutionGroup="o-ex:contextElement"/>
                <!-- Declare new Constraint Elemnts-->
                <xsd:element name="printresolution" type="georel-dd:printResType" substitutionGroup="o-
ex:constraintElement"/>
                <xsd:element name="papersize" type="georel-dd:printPaperType" substitutionGroup="o-ex:constraintElement"/>
                <!-- create new condition elements-->
                <!-- <xsd:element name="commercial " type="georel-dd:CoordinateOperation" substitutionGroup="o-
ex:permissionElement"/>-->
</xsd:schema>
```

Appendix (C): License Scenario 4.4.2 XML instance

- The schema file supplied on CD with this thesis is FTypeLevelLicensexml

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2006 sp1 U (http://www.altova.com) by Mohamed Bishr (EMBRACE) -->
<!-- Mohamed Bishr All Rights Reserved 2006-3- 3-->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:gml="http://www.opengis.net/gml" xmlns:o-
ex="http://odrl.net/1.1/ODRL-EX" xmlns:o-dd="http://odrl.net/1.1/ODRL-DD" xmlns:am="http://www.in.tum.de/am"
xmlns:georel-dd="http://example.net/georel-dd" targetNamespace="http://example.net/georel-dd"
elementFormDefault="qualified" attributeFormDefault="qualified" version="1.1">
	<xsd:annotation>
		<xsd:documentation>
			<version>1.0.0</version>
			<copyright>Copyright (c) 2005-2006 Mohamed Bishr, ITC, All Rights
Reserved</copyright>
		</xsd:documentation>
	</xsd:annotation>
	<!--List Of Imports-->
	<xsd:import namespace="http://odrl.net/1.1/ODRL-EX" schemaLocation="http://www.odrl.net/1.1/ODRL-EX-
11.xsd"/>
	<xsd:import namespace="http://odrl.net/1.1/ODRL-DD" schemaLocation="http://www.odrl.net/1.1/ODRL-DD-
11.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\feature.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\coordinateReferenceSystems.xsd"/>
	<xsd:import namespace="http://www.in.tum.de/am" schemaLocation="C:\Documents and Settings\Mohamed
Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\CityModel\CityModel.xsd"/>
	<!--GREL Schema-->
	<!--declare new GeoREL datatypes-->
	<!--gml boundary to define the dataset boundaries in the context element of any entity specially asset entity-->
	<xsd:complexType name="gmlBoundary">
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:sequence>
					<xsd:element name="DataSetBoundary"
type="gml:BoundingShapeType" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!-- Defining this datatype makes it possible to specifiy application schema features in a rights expression n the
context extity like in an asset element for exmaple-->
	<xsd:complexType name="gmlappSchema">
		<xsd:annotation>
			<xsd:documentation>
datatype is used to construct a context element of Type gml:AbstractFeatureType.
	</xsd:documentation>
		</xsd:annotation>
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:choice>
					<xsd:element name="appschemaElement"
type="gml:AbstractFeatureType"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define a datatype to be used to specify Coordinateoperation using a gml Type to make it possible to specify
same operation defined in GML-->
```

```
	<xsd:complexType name="CoordinateOperation">
		<xsd:complexContent>
			<xsd:extension base="o-ex:permissionType">
				<xsd:choice>
					<xsd:element name="coopID" type="gml:IdentifierType"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define a datatype to be used to specify new requierements-->
	<xsd:complexType name="customerlicense">
		<xsd:complexContent>
			<xsd:extension base="o-ex:requirementType">
				<xsd:choice>
					<xsd:element name="InternalBusinessUse" type="xsd:string"
minOccurs="0"/>
					<xsd:element name="other" type="xsd:string" minOccurs="0"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define new datatypes to be used for a specific variation of print constraints-->
	<xsd:complexType name="printResType">
		<xsd:complexContent>
			<xsd:extension base="o-ex:constraintType">
				<xsd:attribute name="pRes" default="200dpi">
					<xsd:simpleType>
						<xsd:restriction base="xsd:NMTOKEN">
							<xsd:enumeration value="200dpi"/>
							<xsd:enumeration value="300dpi"/>
							<xsd:enumeration value="600dpi"/>
							<xsd:enumeration value="All"/>
						</xsd:restriction>
					</xsd:simpleType>
				</xsd:attribute>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<xsd:complexType name="printPaperType">
		<xsd:complexContent>
			<xsd:extension base="o-ex:constraintType">
				<xsd:attribute name="pSize" default="A4">
					<xsd:simpleType>
						<xsd:restriction base="xsd:NMTOKEN">
							<xsd:enumeration value="A6"/>
							<xsd:enumeration value="A5"/>
							<xsd:enumeration value="A4"/>
							<xsd:enumeration value="A3"/>
							<xsd:enumeration value="A2"/>
							<xsd:enumeration value="A1"/>
							<xsd:enumeration value="A0"/>
						</xsd:restriction>
					</xsd:simpleType>
				</xsd:attribute>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!-- Declare New Requirement elements-->
	<xsd:element name="checkuserlicensetype" type="georel-dd:customerlicense" substitutionGroup="o-
ex:requirementElement"/>
	<!-- Declare New Permession elements-->
	<!-- A permission to grant other permession as opposed to sell, move etc... -->
	<xsd:element name="regrant" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
	<xsd:element name="coordoperation" type="georel-dd:CoordinateOperation" substitutionGroup="o-
ex:permissionElement">
		<xsd:annotation>
```

```
					<xsd:documentation>this element describes a coordinate operation permissions which uses gml:identifierType to describe the operation name equivalent to the GML application schema</xsd:documentation>
				</xsd:annotation>
		</xsd:element>
		<xsd:element name="geometryconversion" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="qualitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="quantitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="newgeometry" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="spatialoperator" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="spatialrelation" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="extractfeature" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<!-- Declare New Context elements-->
		<!-- to decalre geometric boundaries within a given context specially in the asset element representing whole datasets-->
		<xsd:element name="Boundary" type="georel-dd:gmlBoundary" substitutionGroup="o-ex:contextElement"/>
		<xsd:element name="gmlfeature" type="georel-dd:gmlappSchema" substitutionGroup="o-ex:contextElement"/>
		<!-- Declare new Constraint Elemnts-->
		<xsd:element name="printresolution" type="georel-dd:printResType" substitutionGroup="o-ex:constraintElement"/>
		<xsd:element name="papersize" type="georel-dd:printPaperType" substitutionGroup="o-ex:constraintElement"/>
		<!-- create new condition elements-->
		<!-- <xsd:element name="commercial " type="georel-dd:CoordinateOperation" substitutionGroup="o-ex:permissionElement"/>-->
</xsd:schema>
```

Appendix (D): License Scenario 4.4.3 XML instance

- The schema file supplied on CD with this thesis is Previewlicense.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2006 sp1 U (http://www.altova.com) by Mohamed Bishr (EMBRACE) -->
<!-- Mohamed Bishr All Rights Reserved 2006-3- 3-->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:gml="http://www.opengis.net/gml" xmlns:o-ex="http://odrl.net/1.1/ODRL-EX" xmlns:o-dd="http://odrl.net/1.1/ODRL-DD" xmlns:am="http://www.in.tum.de/am" xmlns:georel-dd="http://example.net/georel-dd" targetNamespace="http://example.net/georel-dd" elementFormDefault="qualified" attributeFormDefault="qualified" version="1.1">
	<xsd:annotation>
		<xsd:documentation>
			<version>1.0.0</version>
			<copyright>Copyright (c) 2005-2006 Mohamed Bishr, ITC, All Rights Reserved</copyright>
		</xsd:documentation>
	</xsd:annotation>
	<!--List Of Imports-->
	<xsd:import namespace="http://odrl.net/1.1/ODRL-EX" schemaLocation="http://www.odrl.net/1.1/ODRL-EX-11.xsd"/>
	<xsd:import namespace="http://odrl.net/1.1/ODRL-DD" schemaLocation="http://www.odrl.net/1.1/ODRL-DD-11.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\feature.xsd"/>
	<xsd:import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\coordinateReferenceSystems.xsd"/>
	<xsd:import namespace="http://www.in.tum.de/am" schemaLocation="C:\Documents and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\CityModel\CityModel.xsd"/>
	<!--GREL Schema-->
	<!--declare new GeoREL datatypes-->
	<!--gml boundary to define the dataset boundaries in the context element of any entity specially asset entity-->
	<xsd:complexType name="gmlBoundary">
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:sequence>
					<xsd:element name="DataSetBoundary" type="gml:BoundingShapeType" minOccurs="0"/>
				</xsd:sequence>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!-- Defining this datatype makes it possible to specifiy application schema features in a rights expression n the context extity like in an asset element for exmaple-->
	<xsd:complexType name="gmlappSchema">
		<xsd:annotation>
			<xsd:documentation>
datatype is used to construct a context element of Type gml:AbstractFeatureType.
	</xsd:documentation>
		</xsd:annotation>
		<xsd:complexContent>
			<xsd:extension base="o-ex:contextType">
				<xsd:choice>
					<xsd:element name="appschemaElement" type="gml:AbstractFeatureType"/>
				</xsd:choice>
			</xsd:extension>
		</xsd:complexContent>
	</xsd:complexType>
	<!--define a datatype to be used to specify Coordinateoperation using a gml Type to make it possible to specify same operation defined in GML-->
	<xsd:complexType name="CoordinateOperation">
```

```
				<xsd:complexContent>
					<xsd:extension base="o-ex:permissionType">
						<xsd:choice>
							<xsd:element name="coopID" type="gml:IdentifierType"/>
						</xsd:choice>
					</xsd:extension>
				</xsd:complexContent>
			</xsd:complexType>
			<!--define a datatype to be used to specify new requierements-->
			<xsd:complexType name="customerlicense">
				<xsd:complexContent>
					<xsd:extension base="o-ex:requirementType">
						<xsd:choice>
							<xsd:element name="InternalBusinessUse" type="xsd:string"
minOccurs="0"/>
							<xsd:element name="other" type="xsd:string" minOccurs="0"/>
						</xsd:choice>
					</xsd:extension>
				</xsd:complexContent>
			</xsd:complexType>
			<!--define new datatypes to be used for a specific variation of print constraints-->
			<xsd:complexType name="printResType">
				<xsd:complexContent>
					<xsd:extension base="o-ex:constraintType">
						<xsd:attribute name="pRes" default="200dpi">
							<xsd:simpleType>
								<xsd:restriction base="xsd:NMTOKEN">
									<xsd:enumeration value="200dpi"/>
									<xsd:enumeration value="300dpi"/>
									<xsd:enumeration value="600dpi"/>
									<xsd:enumeration value="All"/>
								</xsd:restriction>
							</xsd:simpleType>
						</xsd:attribute>
					</xsd:extension>
				</xsd:complexContent>
			</xsd:complexType>
			<xsd:complexType name="printPaperType">
				<xsd:complexContent>
					<xsd:extension base="o-ex:constraintType">
						<xsd:attribute name="pSize" default="A4">
							<xsd:simpleType>
								<xsd:restriction base="xsd:NMTOKEN">
									<xsd:enumeration value="A6"/>
									<xsd:enumeration value="A5"/>
									<xsd:enumeration value="A4"/>
									<xsd:enumeration value="A3"/>
									<xsd:enumeration value="A2"/>
									<xsd:enumeration value="A1"/>
									<xsd:enumeration value="A0"/>
								</xsd:restriction>
							</xsd:simpleType>
						</xsd:attribute>
					</xsd:extension>
				</xsd:complexContent>
			</xsd:complexType>
			<!-- Declare New Requirement elements-->
			<xsd:element name="checkuserlicensetype" type="georel-dd:customerlicense" substitutionGroup="o-
ex:requirementElement"/>
			<!-- Declare New Permession elements-->
			<!-- A permission to grant other permession as opposed to sell, move etc... -->
			<xsd:element name="regrant" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
			<xsd:element name="coordoperation" type="georel-dd:CoordinateOperation" substitutionGroup="o-
ex:permissionElement">
				<xsd:annotation>
```

```
					<xsd:documentation>this element describes a coordinate operation permissions which uses gml:identifierType to describe the operation name equivalent to the GML application schema</xsd:documentation>
				</xsd:annotation>
		</xsd:element>
		<xsd:element name="geometryconversion" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="qualitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="quantitativeoperations" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="newgeometry" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="spatialoperator" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="spatialrelation" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<xsd:element name="extractfeature" type="o-ex:permissionType" substitutionGroup="o-ex:permissionElement"/>
		<!-- Declare New Context elements-->
		<!-- to decalre geometric boundaries within a given context specially in the asset element representing whole datasets-->
		<xsd:element name="Boundary" type="georel-dd:gmlBoundary" substitutionGroup="o-ex:contextElement"/>
		<xsd:element name="gmlfeature" type="georel-dd:gmlappSchema" substitutionGroup="o-ex:contextElement"/>
		<!-- Declare new Constraint Elemnts-->
		<xsd:element name="printresolution" type="georel-dd:printResType" substitutionGroup="o-ex:constraintElement"/>
		<xsd:element name="papersize" type="georel-dd:printPaperType" substitutionGroup="o-ex:constraintElement"/>
		<!-- create new condition elements-->
		<!-- <xsd:element name="commercial " type="georel-dd:CoordinateOperation" substitutionGroup="o-ex:permissionElement"/>-->
</xsd:schema>
```

Appendix (E): City Model application schema

- The schema file supplied on CD with this thesis is Previewlicense.xml


```
<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema" xmlns:am="http://www.in.tum.de/am"
xmlns:gml="http://www.opengis.net/gml" xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema–instance" targetNamespace="http://www.in.tum.de/am"
elementFormDefault="qualified">
	<import namespace="http://www.opengis.net/gml" schemaLocation="C:\Documents and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\Base\feature.xsd"/>
	<import namespace="http://www.w3.org/1999/xlink" schemaLocation="C:\Documents and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\xlink\xlinks.xsd"/>
	<element name="CityModel" type="am:CityModelType" substitutionGroup="gml:_FeatureCollection"/>
	<element name="Street" type="am:StreetType" substitutionGroup="gml:_Feature"/>
	<element name="Intersection" type="am:IntersectionType" substitutionGroup="gml:_Feature"/>
	<element name="Building" type="am:BuildingType" substitutionGroup="gml:_Feature"/>
	<complexType name="CityModelType">
		<complexContent>
			<extension base="gml:AbstractFeatureCollectionType"/>
		</complexContent>
	</complexType>
	<complexType name="StreetType">
		<complexContent>
			<extension base="gml:AbstractFeatureType">
				<sequence minOccurs="0">
					<element name="Name"/>
					<element ref="gml:LineString"/>
				</sequence>
			</extension>
		</complexContent>
	</complexType>
	<complexType name="IntersectionType">
		<complexContent>
			<extension base="gml:AbstractFeatureType">
				<sequence minOccurs="0">
					<element name="Name"/>
					<element ref="gml:Point"/>
				</sequence>
			</extension>
		</complexContent>
	</complexType>
	<complexType name="BuildingType">
		<complexContent>
			<extension base="gml:AbstractFeatureType">
				<sequence minOccurs="0">
					<element name="Address"/>
					<element name="Shape" type="gml:PolygonType"/>
				</sequence>
			</extension>
		</complexContent>
	</complexType>
</schema>
```

Appendix (F): City Model XML instance

- The schema file supplied on CD with this thesis is Previewlicense.xml


```
<?xml version="1.0" encoding="UTF-8"?>
<CityModel xmlns="http://www.in.tum.de/am" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:gml="http://www.opengis.net/gml" xmlns:am="http://www.in.tum.de/am"
xmlns:xsi="http://www.w3.org/2001/XMLSchema–instance" xsi:schemaLocation="http://www.in.tum.de/am C:\Documents
and Settings\Mohamed Bishr\My Documents\Msc thesis\Thesis\Chapter 5\GeoODRL\CityModel\CityModel.xsd"
fid="CityModel">
	<gml:boundedBy>
		<gml:Box gid="box1" srsName="foo">
			<gml:coord>
				<gml:X>0</gml:X>
				<gml:Y>0</gml:Y>
			</gml:coord>
			<gml:coord>
				<gml:X>4</gml:X>
				<gml:Y>4</gml:Y>
			</gml:coord>
		</gml:Box>
	</gml:boundedBy>
	<gml:featureMember>
		<Intersection fid="I1">
			<Name>Intersection A</Name>
			<gml:Point srsName="foo">
				<gml:coord>
					<gml:X>0</gml:X>
					<gml:Y>0</gml:Y>
				</gml:coord>
			</gml:Point>
		</Intersection>
	</gml:featureMember>
	<gml:featureMember>
		<Intersection fid="I2">
			<Name>Intersection B</Name>
			<gml:Point srsName="foo">
				<gml:coord>
					<gml:X>0</gml:X>
					<gml:Y>4</gml:Y>
				</gml:coord>
			</gml:Point>
		</Intersection>
	</gml:featureMember>
	<gml:featureMember>
		<Intersection fid="I3">
			<Name>Intersection C</Name>
			<gml:Point srsName="foo">
				<gml:coord>
					<gml:X>2</gml:X>
					<gml:Y>0</gml:Y>
				</gml:coord>
			</gml:Point>
		</Intersection>
	</gml:featureMember>
	<gml:featureMember>
		<Intersection fid="I4">
			<Name>Intersection D</Name>
			<gml:Point srsName="foo">
				<gml:coord>
					<gml:X>2</gml:X>
					<gml:Y>4</gml:Y>
				</gml:coord>
			</gml:Point>
		</Intersection>
```

```
</gml:featureMember>
<gml:featureMember>
	<Intersection fid="I5">
		<Name>Intersection E</Name>
		<gml:Point srsName="foo">
			<gml:coord>
				<gml:X>4</gml:X>
				<gml:Y>2</gml:Y>
			</gml:coord>
		</gml:Point>
	</Intersection>
</gml:featureMember>
<gml:featureMember>
	<Building xsi:type="BuildingType" fid="BuildingA">
		<Address>Street A</Address>
		<Shape srsName="foo">
			<gml:outerBoundaryIs>
				<gml:LinearRing>
					<gml:coord>
						<gml:X>−1</gml:X>
						<gml:Y>2</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>0</gml:X>
						<gml:Y>2</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>0</gml:X>
						<gml:Y>3</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>−1</gml:X>
						<gml:Y>3</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>−1</gml:X>
						<gml:Y>2</gml:Y>
					</gml:coord>
				</gml:LinearRing>
			</gml:outerBoundaryIs>
		</Shape>
	</Building>
</gml:featureMember>
<gml:featureMember>
	<Building xsi:type="BuildingType" fid="BuildingB">
		<Address>Street D</Address>
		<Shape srsName="foo">
			<gml:outerBoundaryIs>
				<gml:LinearRing>
					<gml:coord>
						<gml:X>5</gml:X>
						<gml:Y>4</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>6</gml:X>
						<gml:Y>4</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>6</gml:X>
						<gml:Y>5</gml:Y>
					</gml:coord>
					<gml:coord>
						<gml:X>5</gml:X>
						<gml:Y>5</gml:Y>
					</gml:coord>
					<gml:coord>
```

```xml
                        <gml:X>5</gml:X>
                        <gml:Y>4</gml:Y>
                    </gml:coord>
                </gml:LinearRing>
            </gml:outerBoundaryIs>
        </Shape>
    </Building>
</gml:featureMember>
<gml:featureMember>
    <Street fid="S1">
        <Name>Street A</Name>
        <gml:LineString>
            <gml:coord>
                <gml:X>0</gml:X>
                <gml:Y>0</gml:Y>
            </gml:coord>
            <gml:coord>
                <gml:X>0</gml:X>
                <gml:Y>4</gml:Y>
            </gml:coord>
        </gml:LineString>
    </Street>
</gml:featureMember>
<gml:featureMember>
    <Street fid="S2">
        <Name>Street B</Name>
        <gml:LineString>
            <gml:coord>
                <gml:X>0</gml:X>
                <gml:Y>4</gml:Y>
            </gml:coord>
            <gml:coord>
                <gml:X>2</gml:X>
                <gml:Y>4</gml:Y>
            </gml:coord>
        </gml:LineString>
    </Street>
</gml:featureMember>
<gml:featureMember>
    <Street fid="S3">
        <Name>Street C</Name>
        <gml:LineString>
            <gml:coord>
                <gml:X>0</gml:X>
                <gml:Y>0</gml:Y>
            </gml:coord>
            <gml:coord>
                <gml:X>2</gml:X>
                <gml:Y>0</gml:Y>
            </gml:coord>
        </gml:LineString>
    </Street>
</gml:featureMember>
<gml:featureMember>
    <Street fid="S4">
        <Name>Street D</Name>
        <gml:LineString>
            <gml:coord>
                <gml:X>2</gml:X>
                <gml:Y>4</gml:Y>
            </gml:coord>
            <gml:coord>
                <gml:X>4</gml:X>
                <gml:Y>2</gml:Y>
            </gml:coord>
        </gml:LineString>
```

```
				</Street>
		</gml:featureMember>
		<gml:featureMember>
				<Street fid="S5">
						<Name>Street E</Name>
						<gml:LineString>
								<gml:coord>
										<gml:X>2</gml:X>
										<gml:Y>0</gml:Y>
								</gml:coord>
								<gml:coord>
										<gml:X>4</gml:X>
										<gml:Y>2</gml:Y>
								</gml:coord>
						</gml:LineString>
				</Street>
		</gml:featureMember>
</CityModel>
```