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ISO 19154

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Geographic information — Ubiquitous public access — Reference model

Information géographique — Ubiquitaire l'accès du public — Modèle de référence

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 211, *Geographic information/Geomatics*.

Introduction

Recent advances of web-based and mobile computing technologies have ushered in an era where the general public are not only consumers of content, but also act as creators or providers of new, enriched content.

One sector in particular that is experiencing rapid change and growth is that of geographic information.

"Location" in a general sense is one of the basic requirements of all mobile users. In early development, users were only "consuming" location-based content, but with ever increasingly sophisticated mobile hardware devices and the ever expanding extent of telecommunications networking and sensor web enabled infrastructure, mobile users are now able to create many types of geographic data. Creation of content can be on an individual level, using a coordinate location to enable navigation to a new café described in a blog entry, or as a collaborative effort, such as collecting GPS tracks and incorporating them into the Open Street Map project.

Smaller devices, embedded systems, wireless communication, and sensor networks (ubiquitous computing technologies) require methods of handling geographic information in terms of both production and consumption. Beyond the previously limited public consumption of geographic information, ubiquitous computing technologies provide the infrastructure for the general public to produce, distribute, and consume geographic information. These concepts are manifested as "seamless access from anywhere and at any time to easy-to-use geographic information and services". We refer to these concepts as Ubiquitous Public Access to geographic information.

The goal of ubiquitous public access to geographic information (UPA-to-GI) is to make the user experience of any "smart" device intuitive to understand, along with being easy to use. To achieve this goal, contextual information that is gathered from varied sources is managed efficiently within the UPA architecture. Therefore, systems or services for UPA to geographic information need to support a delivery mechanism of contextual information.

This International Standard defines the requirements of standardization for systems and services supporting ubiquitous public access to geographic information, and describes a comprehensive set of fundamental facets that specify an abstract description of the elements for UPA to geographic information.

This International Standard further establishes a series of models comprised as a conceptual framework that, when implemented, will support the development of a set of systems and services for enabling ubiquitous public access to geographic information. In a UPA environment, general users are no longer only passive consumers of geographic information, but rather active participants in several steps of the data and information management lifecycle such as collection, creation and capture, and/or use and dissemination.

Ubiquitous public access to geographic information might be thought of as a type of geographic information service. However, the currently available standards used in mobile environments are based on web technologies which are not efficient enough to handle the requirements of UPA. In order to provide relevant geographic information to users, the context of the users is described.

The reference model specified here defines a group of models which form a framework that supports methods of extracting geographically explicit context information from varied information sources, such as a lexicon, photos, videos, and others sources. Additional models in the framework specify how geographic data produced and distributed by the general public can be semantically linked to meet the user's contextual requests, and how heterogeneous geographic content can be seamlessly accessed, integrated, and provided to a user regardless of the kind of device the user operates.

Geographic information — Ubiquitous public access — Reference model

1 Scope

This International Standard defines a reference model for ubiquitous public access (UPA) to geographic information. This reference model uses standard concepts from both the Open distributed processing — Reference model (RM-ODP) in ISO/IEC 10746-1 and ISO 19101.

The reference model specified in this International Standard defines the following:

— conceptual models for ubiquitous public access (UPA) to geographic information;

— a reference model and framework to support current and future specification development in this area;

— the semantics of information and processing within systems and services for the UPA of geographic information;

— the architectural relationship between this International Standard and other ISO geographic information standards.

This International Standard is applicable to location-based services (LBS), ubiquitous computing environments, linked open data, and other domains that require a seamless public access to geographic information.

Although structured in the context of information technology and information technology standards, this International Standard is independent of any application development method or technology implementation approach.

2 Conformance

General conformance and testing requirements are defined in ISO 19105. Conformance requirements are specified in Annex A.

3 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19101-1:2014, *Geographic information — Reference model — Part 1: Fundamentals*

ISO/TS 19101-2:2008, *Geographic information — Reference model — Part 2: Imagery*

ISO 19103:—[1)], *Geographic information — Conceptual schema language*

ISO 19109:—[2)], *Geographic information — Rules for application schema*

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) To be published.

2) To be published.

4.1
ambient intelligence
convergence of ubiquitous computing, ubiquitous communication, and interfaces adapting to the user

4.2
application
manipulation and processing of data in support of user requirements

[SOURCE: ISO 19101-1:2014, 4.1.1]

4.3
computational viewpoint
viewpoint (4.29) on an ODP system and its environment which enables distribution through functional decomposition of the system into objects which interact at *interfaces* (4.13)

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.3]

4.4
context
aspects or properties of an entity that affect the behaviour or expectations of that entity in any given situation

4.5
context-awareness
integrated operations to collect and deliver *context* (4.4) specific information, and convert it to tailored data for each user

EXAMPLE getContext(staticFeature) = FD_Feature

Note 1 to entry: In the example, the getContext operation would extract geographically explicit context information FD_Feature from varied information sources, such as photos, videos, etc.

4.6
enterprise viewpoint
viewpoint (4.29) on an ODP system and its environment that focuses on the purpose, scope, and policies for that system

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.1]

4.7
geographic context awareness
application (4.2) or *service* (4.23) behaviour based on the recognition of user's geographic *context* (4.4)

4.8
geographic information
information concerning phenomena implicitly or explicitly associated with a location relative to the Earth

[SOURCE: ISO 19101-1:2014, 4.1.18]

4.9
geographic information service
service (4.23) that transforms, manages, or presents geographic information to users

[SOURCE: ISO 19101-1:2014, 4.1.19]

4.10
geographic information system
information system dealing with information concerning phenomena associated with location relative to the Earth

[SOURCE: ISO 19101-1:2014, 4.1.20]

4.11
information system
information processing system, together with associated organizational resources such as human, technical, and financial resources, that provides and distributes information

[SOURCE: ISO/IEC 2382-1:1993]

4.12
information viewpoint
viewpoint (4.29) on an ODP system and its environment that focuses on the semantics of information and information processing

[SOURCE: ISO/IEC 10746-3:2009, 4.1.1.2]

4.13
interface
named set of *operations* (4.17) that characterize the behaviour of an entity

[SOURCE: ISO 19119:2005, 4.2]

4.14
interoperability
capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

[SOURCE: ISO/IEC 2382-1:1993, 01.01.47]

4.15
linked geodata
geographic data and information sources published on the *Semantic Web* (4.22)

Note 1 to entry: These publicly available geographic data and information sources are published in a standardized formal model.

4.16
ontology
formal representation of phenomena of a *universe of discourse* (4.28) with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships

[SOURCE: ISO 19101-1:2014, 4.1.26]

4.17
operation
specification of a transformation or query that an object may be called to execute

[SOURCE: ISO 19119:2005, 4.3]

4.18
public access
open access to information sources and/or *services* (4.23) by general public users and professional users alike

4.19
reference model
framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment

Note 1 to entry: A reference model is based on a small number of unifying concepts and can be used as a basis for education and explaining standards to a non-specialist.

[SOURCE: ISO 14721:2003, 1.7.2.63, modified — the second sentence in definition has been made a note to entry.]

4.20
schema
formal description of a model

[SOURCE: ISO 19101-1:2014, 4.1.34]

4.21
seamless mobility
continuous and intuitive access to various information sources and *services* (4.23) regardless of protocols, networks, frequency bands, and physical environments

4.22
Semantic Web
Web (4.30) of data with meaning

Note 1 to entry: The association of meaning allows data and information to be understood and processed by automated tools as well as by people.

[SOURCE: ISO 19101-1:2014, 4.1.35]

4.23
service
distinct part of the functionality that is provided by an entity through *interfaces* (4.13)

[SOURCE: ISO 19119:2005, 4.1]

4.24
service broker
application (4.2) that combines or offers lower-level *services* (4.23) for specific user needs

[SOURCE: ISO 19132:2007, 4.46]

4.25
ubiquitous public access
UPA
service (4.23) that enables end-users to have easy and interoperable access to specific types of data, irrespective of their location or access device, and that match their interest criteria

EXAMPLE Linked Geodata Service

Note 1 to entry: In the example, the Linked GeoData Service is responsible for openly inter-connecting geographic information to external repositories or web resources using a transform to either Resource Description Framework (RDF) or Web Ontology Language (OWL) format.

4.26
ubiquitous geographic information
geographic information (4.8) provided to users following the concepts of *ubiquitous public access* (4.25)

4.27
universal representation
universal feature model to be specified without knowing users' structures or abstraction models

4.28
universe of discourse
view of the real or hypothetical world that includes everything of interest

[SOURCE: ISO 19101-1:2014, 4.1.38]

4.29
viewpoint (on a system)
form of abstraction achieved using a selected set of architectural concepts and structuring rules, in order to focus on particular concerns within a system

[SOURCE: ISO/IEC 10746-2:2009, 3.2.7]

4.30
World Wide Web
Web
universe of network-accessible information and *services* (4.23)

[SOURCE: ISO 19101-1:2014, 4.1.40]

4.31
Web service
service (4.23) that is made available through the *Web* (4.30)

Note 1 to entry: A Web service usually includes some combination of programming and data. It can also include human resources.

[SOURCE: ISO 19101-1:2014, 4.1.41]

5 Symbols (and abbreviated terms)

5.1 Abbreviated terms

API	Application Programming Interface
CRS	Coordinate Reference System
FOAF	Friend of a Friend
GeoRSS	Geographic Rich Site Summary
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
LBS	Location-based Service
LGD	Linked GeoData
OGC	Open Geospatial Consortium
OMG	Object Management Group
OWL	Web Ontology Language
RDF	Resource Description Framework
RM-ODP	Reference Model of Open Distributed Processing (ISO/IEC 10746)
SRS	Spatial Reference System
UML	Unified Modeling Language
UPA-to-GI	Ubiquitous Public Access to Geographic Information

URI Uniform Resource Identifier

XML eXtensible Markup Language

5.2 UML notation

The notation used in this International Standard as conceptual models of information systems and services are presented using the Unified Modeling Language as specified in ISO 19103.

6 Reference model requirements

6.1 Background

Today, with the rapid spread of small and powerful mobile devices, the general public is not only consuming various types of content embedded with geographic information, but they are also creating similar content.

Computing advances in seamless mobility, context awareness, sensor networks, and cloud computing have led to the emergence of applications and services many of which are based on, or related to, geographic information.

The widespread availability of telecommunication and networking infrastructure, coupled with the ever increasingly degree of "smart" mobile hardware devices and accompanying software and services, is enabling the general public to access and use geographic information services frequently, and without actually realizing it.

Within the field of geographic information systems and services, ubiquitous public access to geographic information (UPA-to-GI) consists of the following two concepts:

— ubiquity;

— public access.

In order to address the needs of users and providers requiring access to geographic information under ubiquitous computing infrastructure, this International Standard defines a reference model for UPA-to-GI using the viewpoints based on the model specified in ISO 19101-1:2014 and RM-ODP system architecture approach as specified by ISO/IEC 10746.

Clause 7 defines the RM-ODP viewpoints of this reference model. Further details are specified in

— enterprise viewpoint with UPA-to-GI related services (7.1),

— information viewpoint for three types of geographic context (7.2), and

— computational viewpoint for UPA-to-GI services (7.3).

To aid developers implementing systems based on the reference model defined in this International Standard, additional background and related standards activities, example conceptual service architecture design, and use case scenarios are presented in the following annexes.

— Annex A defines the abstract test suite for conforming to the reference model specified in this International Standard.

— Annex B provides additional background on the concepts of UPA-to-GI.

— Annex C describes the RM-ODP viewpoints for UPA-to-GI Reference Model.

— Annex D presents the conceptual service architecture for UPA-to-GI.

— Annex E examines a number of existing and in-progress standardization efforts by ISO, OGC, and other standards bodies.

— Annex F presents three UPA-to-GI service scenarios to help developers visualize the merits of UPA-to-GI.

6.2 Design principles of ubiquitous public access

When considering the design of ubiquitous public access systems, this International Standard presents two motivating factors that comprise the fundamental principal of UPA-to-GI.

a) The standardization of geographic information systems/services will enable end-users to have access to geographic information meeting their needs in a convenient and interoperable manner.

b) The use of ubiquitous computing technologies will enable an augmented and intelligent information infrastructure.

Figure 1 visually presents these two motivating factors of the design of a service environment for UPA-to-GI. These systems and services function as an effective interface between emerging ubiquitous computing technology and traditional geographic information services within a new information and communication technology (ICT) ecosystem.

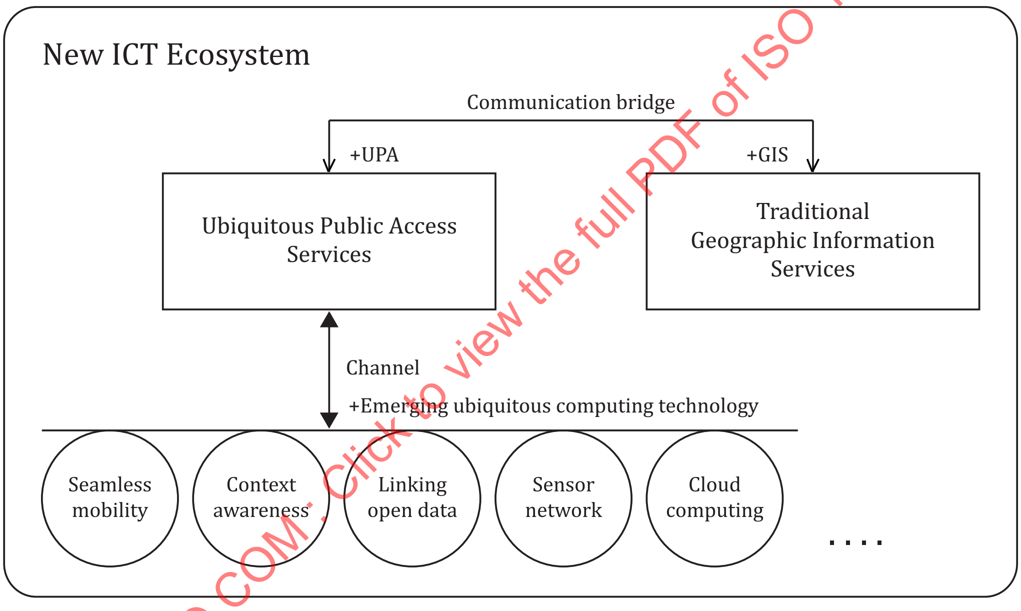

Figure 1 — Two motivating factors of ubiquitous public access

6.3 Semantics of UPA

6.3.1 Overview

Three semantic properties can be used to more clearly describe the requirements of the UPA-to-GI reference model defined in this International Standard. The three required semantic properties are the following:

— ubiquity of geographic information (6.3.2);

— degree of public access (6.3.3);

— ubiquitous public access (6.3.4).

6.3.2 Ubiquity of geographic information

Within a ubiquitous computing environment, end-users make use of varied geographic information services based on “ambient intelligence”.

To enable the understanding of ambient intelligence for geographic information, this International Standard specifies the context information model for supporting UPA-to-GI as defined in 7.2.2.

This context model is based on seamless mobility and geographic context.

Seamless mobility provides mobile users with continuous and intuitive access to various information sources and services including geographic information services regardless of protocols, networks, frequency bands, and physical environments.

Geographic context awareness uses ambient intelligence to gather specific context of the user which may include identity, time, activity, and the location of the user. Once the geographic context of a user is extracted, information services are able to provide rich and high quality ambient intelligence to the user.

The geographic context can include one's individual context (e.g. location, speed, and orientation), static context (geographic information), and dynamic context (e.g. weather, traffic conditions, data from sensor, and more).

6.3.3 Degree of public access

Public access to geographic information implies easy or open access to geographic information sources and/or services by general public users and professional users alike. Greater emphasis is placed on the ease-of-use of geographic information services for the general public.

This International Standard presents the following two concepts to clarify the degree of public access required for UPA-to-GI systems.

a) Universal representation refers to any request from a user for any type of geographic information service (an LBS request, map display, etc.) and implies that the request shall be unambiguously specified, without requiring the details of the underlying structures or abstraction models, using the universal feature model defined in ISO 19109.

b) Linked open geodata refers to publicly available open geographic data and information sources. The reference model defined in this International Standard identifies areas in which there are further standards for public access to geographic information sources through the Linking Open GeoData framework.

6.3.4 Ubiquitous Public Access

As specified in this reference model, UPA-to-GI services infer and extract the geographical context of various types of non-geographic information embedded with geospatial semantics.

This reference model also provides a framework for an open access environment to enable the linking of geographic data, including data from other sources, along with those produced by the users. The result of this linking will facilitate easy and seamless access to geographic information services regardless of a user's computing environment.

6.4 Conceptual framework

The reference model defined in this International Standard specifies a conceptual framework clarifying how the domain of ubiquitous computing and geographic information are interconnected through a logical environment for a set of applications and processed within each domain.

Figure 2 illustrates a conceptual framework where varied implicit geographic information of a user retrieved from a ubiquitous computing infrastructure can be effectively processed by different geographic information services defined within a UPA-to-GI system.

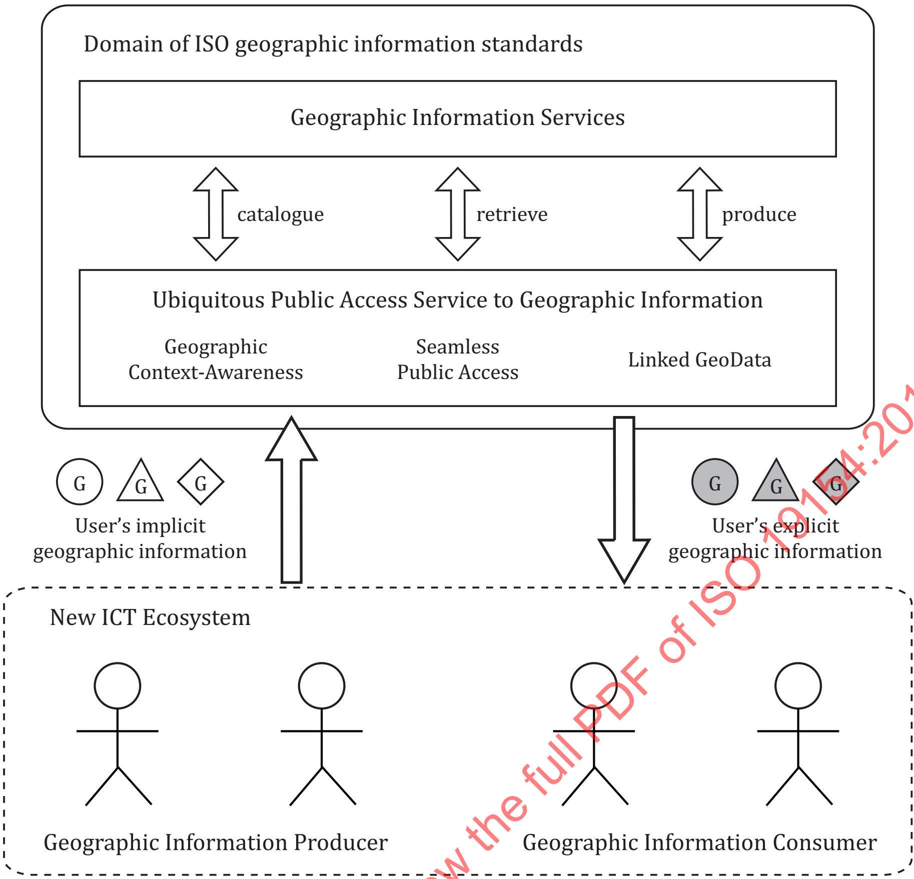

Figure 2 — Conceptual framework of ubiquitous public access to geographic information

As shown in Figure 2, a user, either a human or machine, can receive requested information from an application service, which is relevant to the current context of the user. The current contextual information of the user is retrieved through various mechanisms, such as positioning devices or sensor networks that are available within a ubiquitous computing infrastructure.

The application service to which the user is currently subscribed will then send, using a network infrastructure, the contextual information to the ubiquitous public access interface.

Relevant UPA services will transform implicit geographic information, which is tacit in nature and not documented nor clearly expressed, into explicit geographic information which is well documented and clearly expressed.

This explicit geographic information can be accessed from a repository, using the contextual information of the user by interoperating with other relevant geographic information services. The application service can further interoperate with other general information services to meet any additional, non-geographic requests of the user.

6.5 Relationship with other ISO geographic information standards

6.5.1 Overview

The reference model defined in this International Standard occupies a close and important relationship with other ISO geographic information standards. This reference model builds on the existing ISO 19101-1:2014 reference model fundamentals and also ISO/TS 19101-2:2008 reference model for imagery and gridded data.

Both ISO 19101-1:2014 and ISO/TS 19101-2:2008 define the framework for standardization in the field of geographic information and establish the basic principles by which those standardization activities take place. Although structured in the context of information technology and information technology standards, both ISO 19101-1:2014 and ISO/TS 19101-2:2008 are independent of any application development method or technology implementation approach.

6.5.2 Relationship with ISO 19101

Within the suite of ISO geographic information standards, ISO 19101-1:2014 and ISO/TS 19101-2:2008 define the reference model and conceptual framework for the interoperability of geographic information. ISO 19101-1:2014 further specifies three foundations that comprise the ISO geographic information series of standards:

— semantic foundation;

— syntactic foundation;

— service foundation.

In addition to these three foundations, the reference model defined in ISO 19101-1:2014 further adopts four levels of conceptualization:

— meta-meta level;

— meta level;

— application level;

— instance level.

Table 1 shows the correspondence between the foundation levels and conceptualization levels as defined in ISO 19101-1:2014.

Table 1 — Positioning of the UPA-to-GI reference model within the ISO 19101-1 conceptual framework

Level/ Foundation	Interoperability			Procedural standards
	Semantic foundation	Syntactic foundation	Service foundation	
Meta-meta	Meta-meta:Semantic	Meta-meta:Syntactic	Meta-meta:Service	Meta-meta:Procedural
Meta	Meta:Semantic	Meta:Syntactic	Meta:Service	Meta:Procedural
Application	Application:Semantic	Application:Syntactic	Application:Service	Application:Procedural
Instance	Instance:Semantic	Instance:Syntactic	Instance:Service	Instance:Procedural

The UPA-to-GI reference model defined in this International Standard specifies areas that are directly implementable in addition to application schemas that are specifically required in a system/service for UPA-to-GI. Therefore, this reference model is positioned within the service foundation at the application level.

The UPA-to-GI reference model does not specify the syntactic foundation. Instead, this reference model can include XML encodings to represent geographic information, as well as portrayal rules and catalogues serviced through the other ISO geographic information standards, which provide the syntactic foundation.

The UPA-to-GI concepts defined in this reference model serve as the processing and service foundation at the meta-meta level as specified in ISO 19101-1:2014 as this reference model provides the definition of rules and methodologies for specifying ubiquitous public access to geographic information.

6.5.3 Relationship with other ISO geographic information standards

As shown in Figure 3, this International Standard is denoted by "ISO 19154 UPA Reference Model" package at the centre of the figure, and refers to the other ISO geographic information standards (Existing ISO 19100 Standards). Since this reference model is positioned at the application level in the semantic foundation, this International Standard refers to meta-meta level standards, such as ISO 19101-1:2014 and ISO 19103:—[3] for its semantic foundation.

This International Standard also provides an enhanced semantic foundation as well as service foundation for other future new UPA standards.

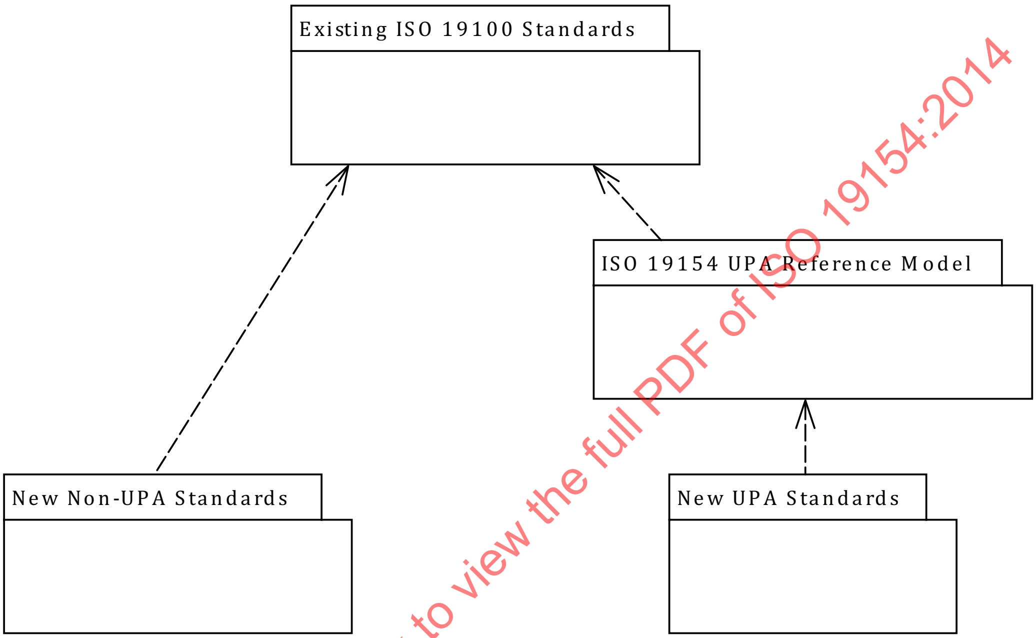

Figure 3 — Dependencies with other ISO geographic information standards

6.6 Other areas of standardization

6.6.1 Standards to allow public access to users

The first category of standards for UPA includes the standards for the UPA services offered to public users. Even though a number of ISO/TC 211 standards belong to this category, they are focused on the consumption of geographic information. UPA services standards for not only public consumption but also public production of geographic information are needed.

6.6.2 Standards to manage geographic information for public access

The standards of the second category are intended to manage geographic information for UPA. The standards for the production and management of geographic information belong to this category. Since the geographic information produced by public users can have accuracy and consistency problems, more rigorous specifications and standards for data quality and metadata are required. Also, in order to integrate multiple sources of geographic information, standards for global identifiers are needed.

6.6.3 Standards to incorporate ubiquitous technologies into public access

The third category of standards for UPA is to incorporate ubiquitous computing technologies into UPA. First of all, context-awareness is an essential function not only for ubiquitous computing but also

3) To be published.

for public access to geographic information. Spatial awareness, which is a kind of context-awareness, is particularly important for UPA. Note that spatial awareness is no longer limited to a service that UPA provides to users with user-interfaces; spatial awareness is also a useful function of any type of pervasive computing device. The massively distributed architecture of ubiquitous computing and its middleware are also important issues to be considered for standardization in UPA.

6.6.4 Additional information on areas of standardization

Annex D presents detailed information on a number of existing standardization efforts taking place in various standards bodies that are directly related to the requirements of UPA-to-GI.

7 RM-ODP viewpoints

7.1 Enterprise viewpoint

7.1.1 Introduction

The enterprise viewpoint focuses on the purpose, scope, and policies of a system or service environment for UPA-to-GI.

As shown in Figure 4, the enterprise viewpoint identifies enterprise objects that specify different roles in the UPA-to-GI environment. These roles are defined in the following subclauses:

— user (7.1.2);

  — geographic information consumer (7.1.2.2);

  — geographic information producer (7.1.2.3);

— UPA service provider (7.1.3);

— geographic context producer (7.1.4).

The enterprise viewpoint for UPA-to-GI identifies three use cases depicting the processing and the interactions among the identified roles. Those use cases are the following:

a) seamless public access;

b) geographic context-awareness;

c) linked geodata under the existing geographic information services.

The enterprise viewpoint further identifies four roles that can be used as resources for various implementations from this conceptual model. Those roles include the following:

— location context;

— geospatial context;

— geosemantic context;

— features.

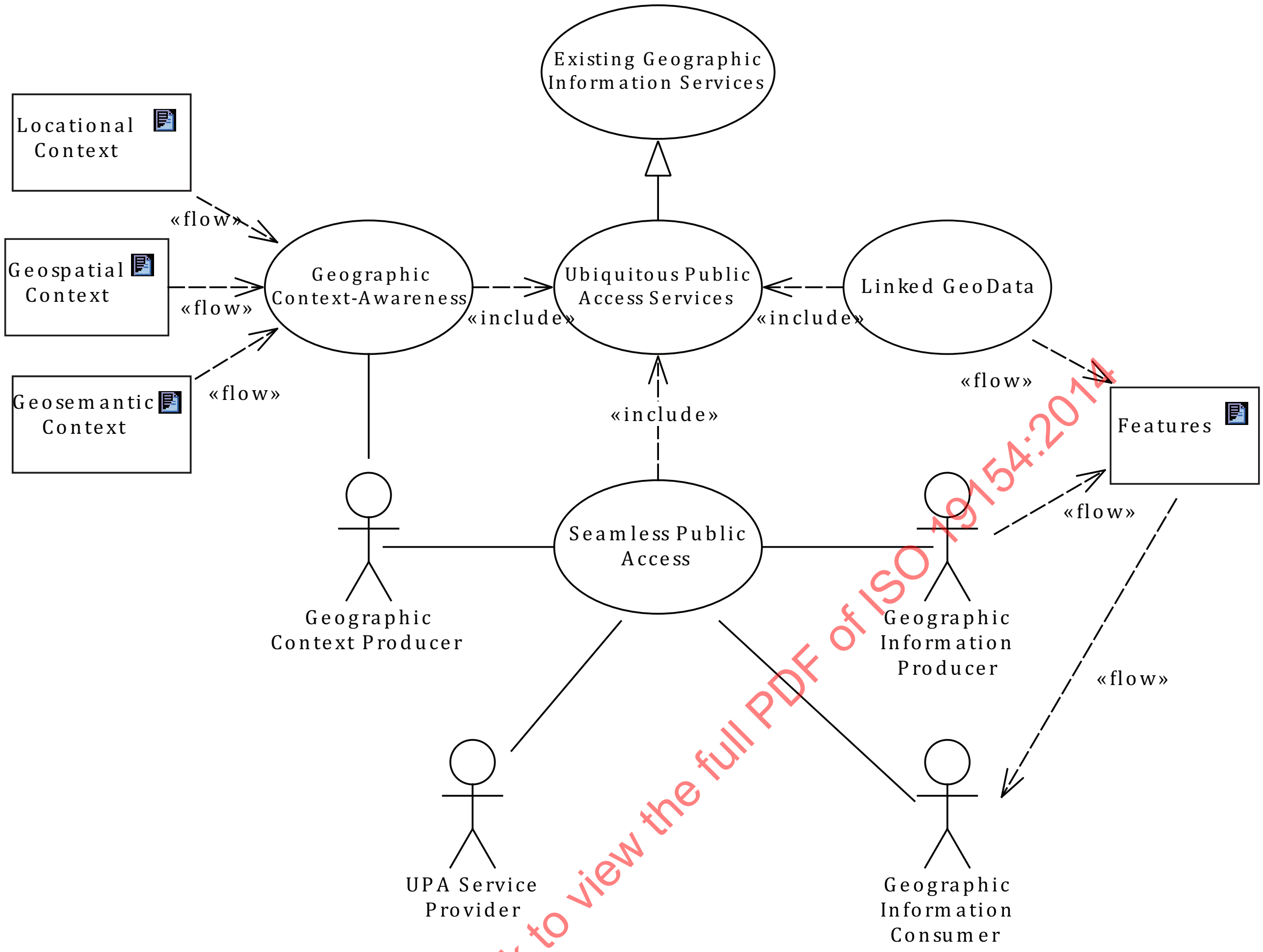

Figure 4 — Enterprise viewpoint

7.1.2 User (producer and consumer)

7.1.2.1 Overview

A user is a person or a device that can communicate with geographic information application providers through seamless public access mechanisms, which enable that user access to geospatial applications subscribed over network infrastructures anywhere and anytime. There are two types of users in the environment of UPA-to-GI:

— geographic information consumer (7.1.2.2);

— geographic information producer (7.1.2.3).

7.1.2.2 Geographic information consumer

A geographic information consumer is a member of the public who requests geographic information from application providers through either explicit requests or push/pull operations from the user's device when triggered by the geographic context.

Related to the geographic information consumer, the following three types of geographic context may be inferred by a geographic context producer:

— locational context;

— geospatial context;

— geosemantic context.

In addition, a geographic information consumer may utilize linked geodata in order to access publicly available open geographic data and information sources.

7.1.2.3 Geographic information producer

A geographic information producer is a skilled member of the general public who creates and shares geographic data and/or geographic information through application providers using seamless public access mechanisms.

The geographic context of a geographic information producer can be inferred through a well-defined set of geographic context-aware processes from a geographic context producer.

A geographic information producer creates well-defined features that universally represent all types of geographic information in an unambiguous way. In addition, those features can be publicly accessible via Linked GeoData mechanisms.

7.1.3 UPA service provider

In a ubiquitous computing infrastructure, a UPA service provider enables various application objects in a UPA-to-GI environment to communicate with each other in a seamless manner via open interfaces between different components and geographic information applications.

As shown in Figure 4, the mechanism for seamless public access to geographic information should include standardized interfaces to varied ubiquitous computing infrastructures such as sensor networks.

7.1.4 Geographic context producer

A geographic context producer is a type of geographic information service provider that can extract contextual information via the process of geographic context-awareness, which eventually extracts or infers three types of geographic context information: location context, geospatial context, and geosemantic context.

A geographic context producer plays a key role in making geographic information services intelligent and ubiquitous by enabling context-aware geographic information services.

A geographic context producer implements the mechanism of seamless public access between ubiquitous public access services and geographic information services in order to extract relevant geographic contexts of the users (i.e. geographic information consumers and geographic information producers).

7.2 Information viewpoint

7.2.1 Overview

Information viewpoint focuses on the data as well as its semantics. This viewpoint describes the information managed by the system along with the structure and content type of the supporting data.

The semantics and requirements for the processing of UPA service information using UML schema definitions are specified in 7.2.2 and 7.3.2.

The information viewpoint in this International Standard provides a general feature model in which all feature types have linked proprieties, attributes or associations, and operations, in one or multiple domains of discourse.

7.2.2 Context information model

This International Standard specifies the UPA Context Information Model, as shown in Figure 5, using the following three sub-packages:

— UPA Locational Context (7.2.3);

— UPA Geospatial Context (7.2.4);

— UPA GeoSemantic Context (7.2.5).

The UPA Context Information Model conceptualizes a standardized mechanism for an information system or service to extract different levels of context on geographic information such as various representations of locations about the users.

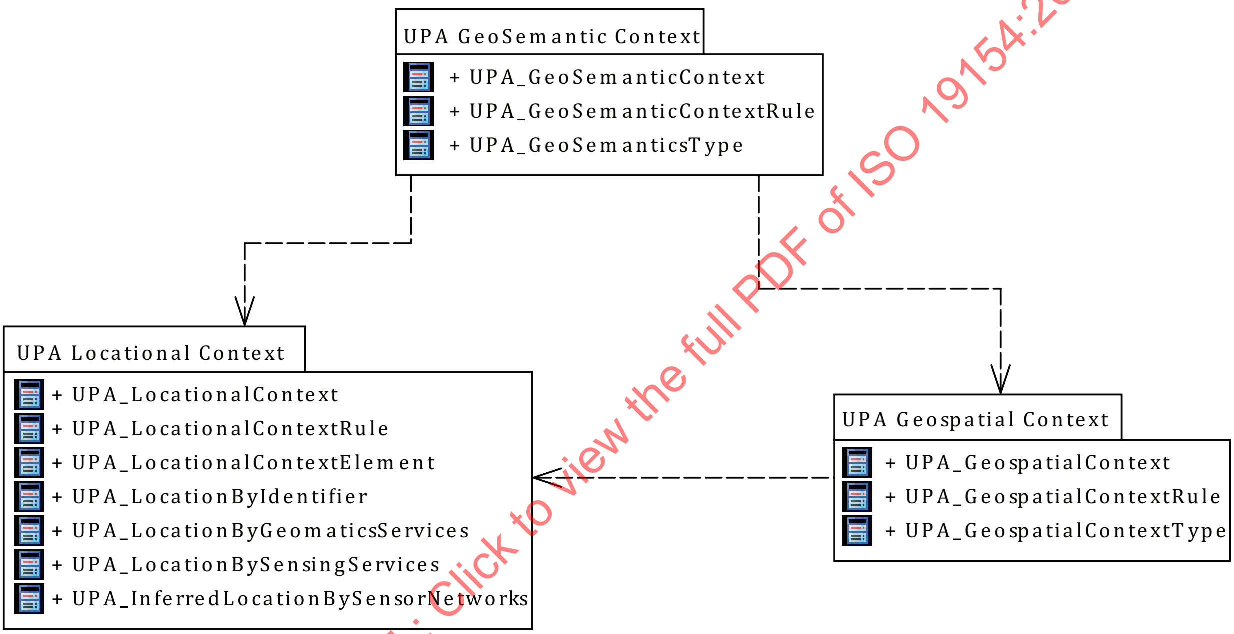

Figure 5 — Sub-packages of the UPA Context Information model

7.2.3 Package — UPA Locational Context

7.2.3.1 Overview

The UPA Locational Context package contains core classes and their associations for retrieving locational context from various types of location representations. These classes include

— UPA_LocationalContext (7.2.3.2),

— UPA_LocationalContextRule (7.2.3.3),

— UPA_LocationalContextElement (7.2.3.4),

— UPA_LocationByIdentifier (7.2.3.5),

— UPA_LocationByGeomaticsServices (7.2.3.6),

— UPA_LocationBySensingServices (7.2.3.7), and

— UPA_InferredLocationBySensorNetworks (7.2.3.8).

Figure 6 shows the associations of these classes listed above.

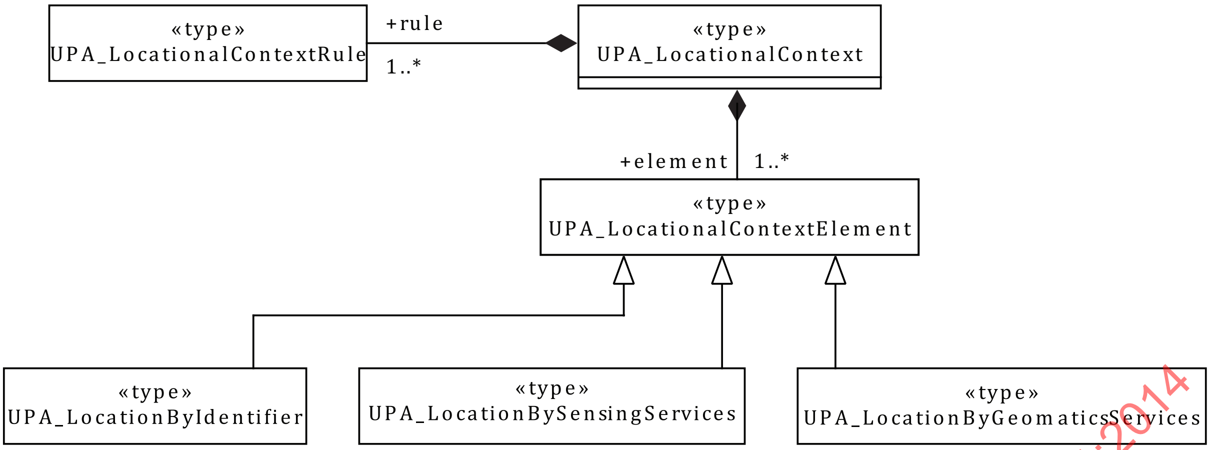

Figure 6 — UPA_LocationalContext associations

7.2.3.2 Type — UPA_LocationalContext

The type UPA_LocationalContext, as shown in Figure 6, is a root class for an object that can be represented with any type of locational representation. UPA_LocationalContext is composed of one or more UPA_LocationalContextRule types.

7.2.3.3 Type — UPA_LocationalContextRule

The type UPA_LocationalContextRule, as shown in Figure 6, is an abstract class that can be defined as the rules to infer relevant locational context from the location information of the user.

7.2.3.4 Type — UPA_LocationalContextElement

The type UPA_LocationalContextElement, also shown in Figure 6, is an abstract class that can further specify three ways of retrieving location information of the user.

7.2.3.5 Type — UPA_LocationByIdentifier

The type UPA_LocationByIdentifier, as shown in Figure 7, is a class containing any number of UPA locations that can be expressed by identifiers such as PI_LocationInstance, from ISO 19155:2012.

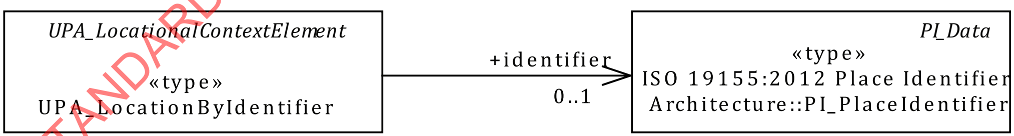

Figure 7 — UPA_LocationByIdentifier associations

7.2.3.6 Type — UPA_LocationByGeomaticsServices

The type UPA_LocationByGeomaticsServices, as shown in Figure 8, is a class of any number of UPA locations that can be expressed by various geomatics services such as LR_PositionExpression (from ISO 19148), LBS_Location (from ISO 19132), MF_PositionExpression (from ISO 19141), and TN_Location (from ISO 19147).

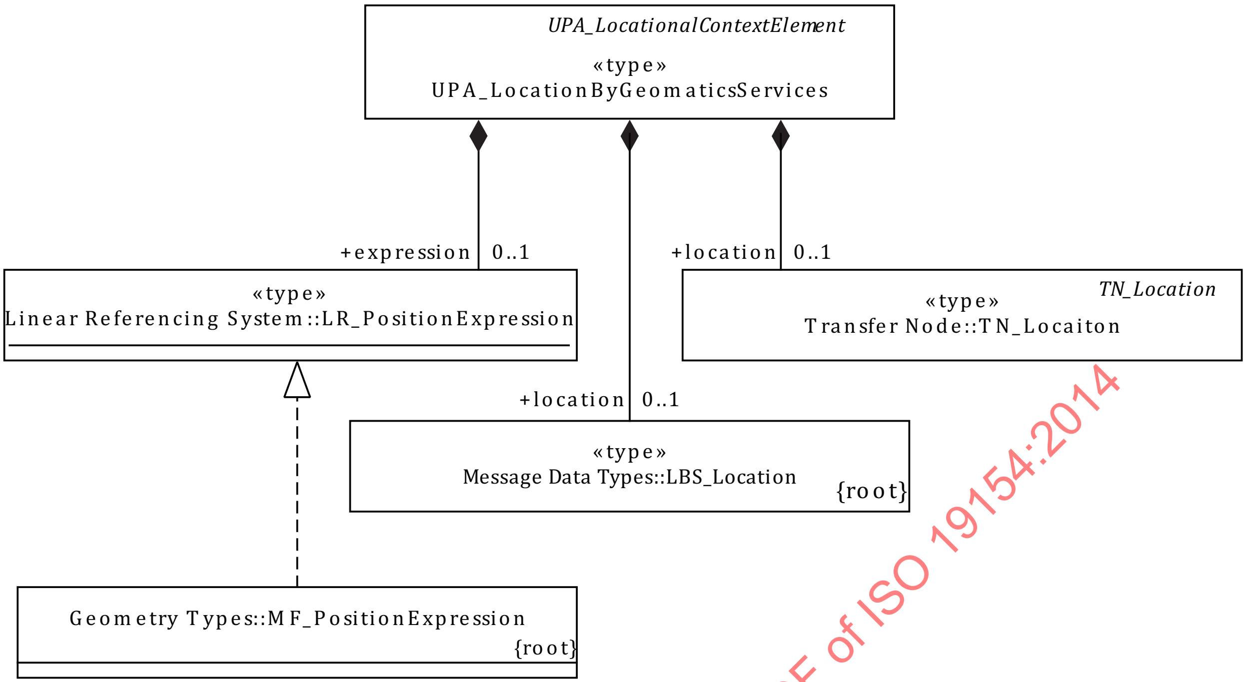

Figure 8 — UPA_LocationByGeomaticsServices associations

7.2.3.7 Type — UPA_LocationBySensingServices

The type UPA_LocationBySensingServices, as shown in Figure 9, is a class of any number of UPA locations that can be expressed by various sensing services such as SD_PositionAndOrientation (from ISO/TS 19130) and a new class, UPA_InferredLocationBySensorNetworks, as specified in this International Standard.

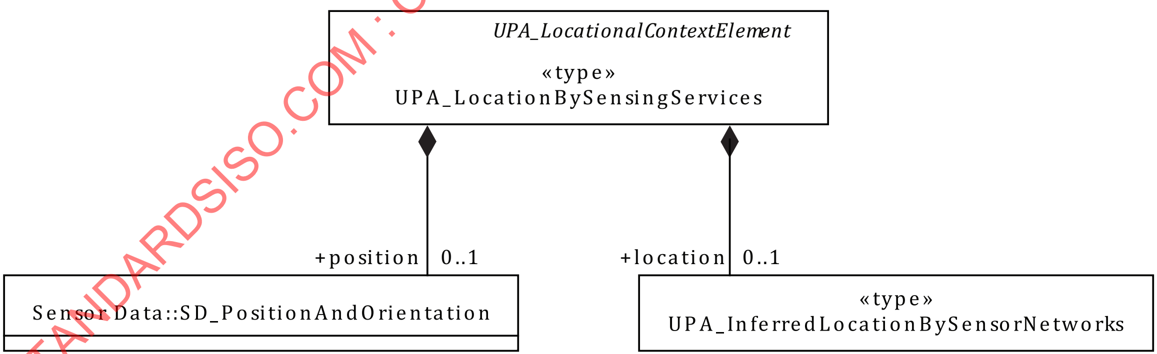

Figure 9 — UPA_LocationBySensingServices associations

7.2.3.8 Type — UPA_InferredLocationBySensorNetworks

The type UPA_InferredLocationBySensorNetworks, as shown in Figure 9, is a class of inferred location from various sensor networks. This type will be realized from several interfaces depending on other standards that define the various sensor networks, and can communicate with external service providers that can infer different types of location for users/actors/sensors using multiple sensor networks.

7.2.4 Package — UPA Geospatial Context

The type UPA_GeospatialContext, as shown in Figure 10, is a class of inferred geospatial context from the locational context of a user.

This International Standard does not specify a mechanism for identifying geospatial context of a user as those mechanisms shall be provided by the application providers. Instead, this International Standard specifies what types of geospatial entities can be retrieved from those mechanisms that represent the geospatial context of a user as supplied by the application providers.

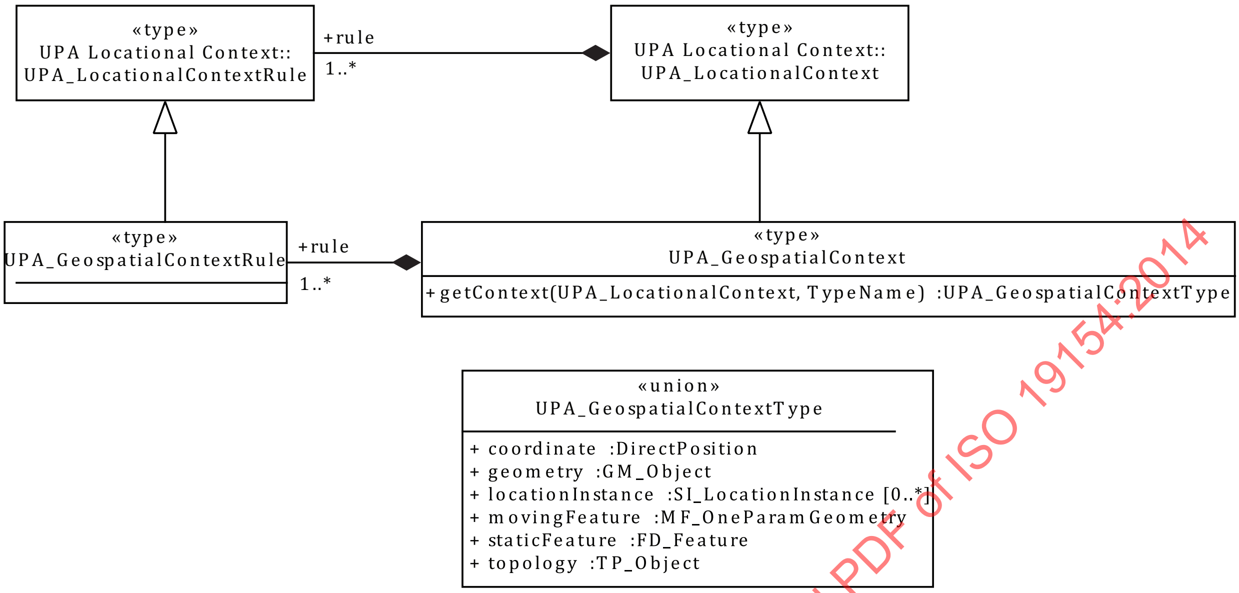

Figure 10 — UPA_GeospatialContext associations

7.2.5 Package — UPA GeoSemantic Context

The type UPA_GeoSemanticContext, as shown in Figure 11, is a class of inferred geosemantic context containing the location context of a user. This class requires the following types:

— UPA_GeoSpatialContext;

— UPA_GeoSemanticContextRule;

— UPA_GeoSemanticsType.

The type UPA_GeoSemanticsType, also shown in Figure 11, is a class of any number of semantic expressions that can be specified by ISO/TC 211 International Standards or other related specifications of semantics for geographic information.

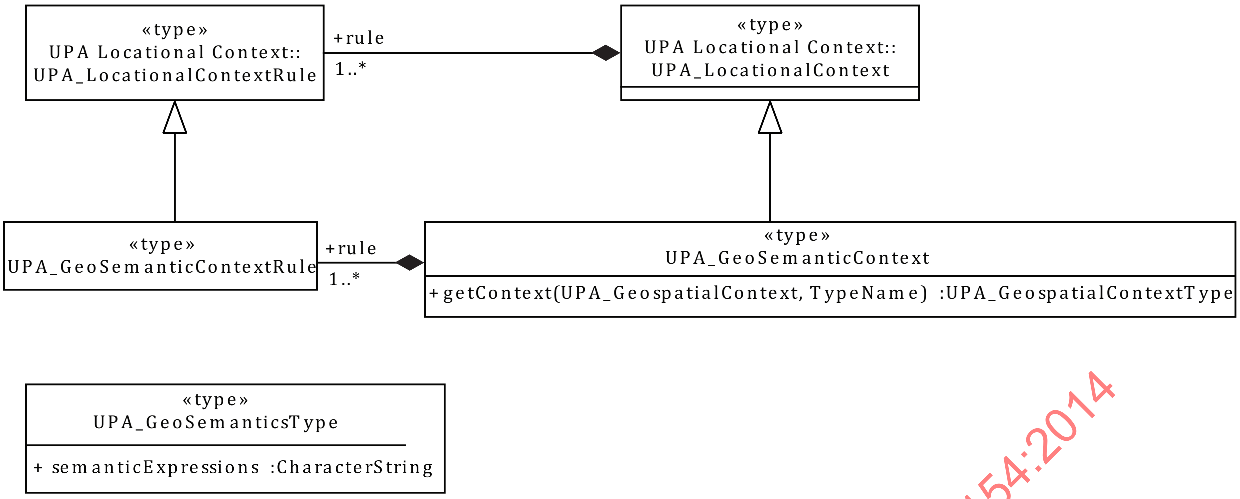

Figure 11 — UPA_GeoSemanticContext associations

7.3 Computational viewpoint

7.3.1 Overview

Computation viewpoint enables distribution through the functional decomposition of the system into objects which interact at interfaces. The computation viewpoint describes the functionality provided by the system and its functional decomposition. 7.3.2 and 7.3.3 describe the functionalities of a UPA service/system using UML operation definitions, which are consistent with the enterprise and information viewpoints.

7.3.2 Context Producing Service model

7.3.2.1 Semantics

The type UPA_ContextProducingService, as shown in Figure 12, is a root class consisting of three types of context producing services:

— UPA_LocationalContextProducingService;

— UPA_GeospatialContextProducingService;

— UPA_GeoSemanticContextProducingService.

These three services are triggered by the type UPA_ContextTrigger which is a class of any location representations for the user.

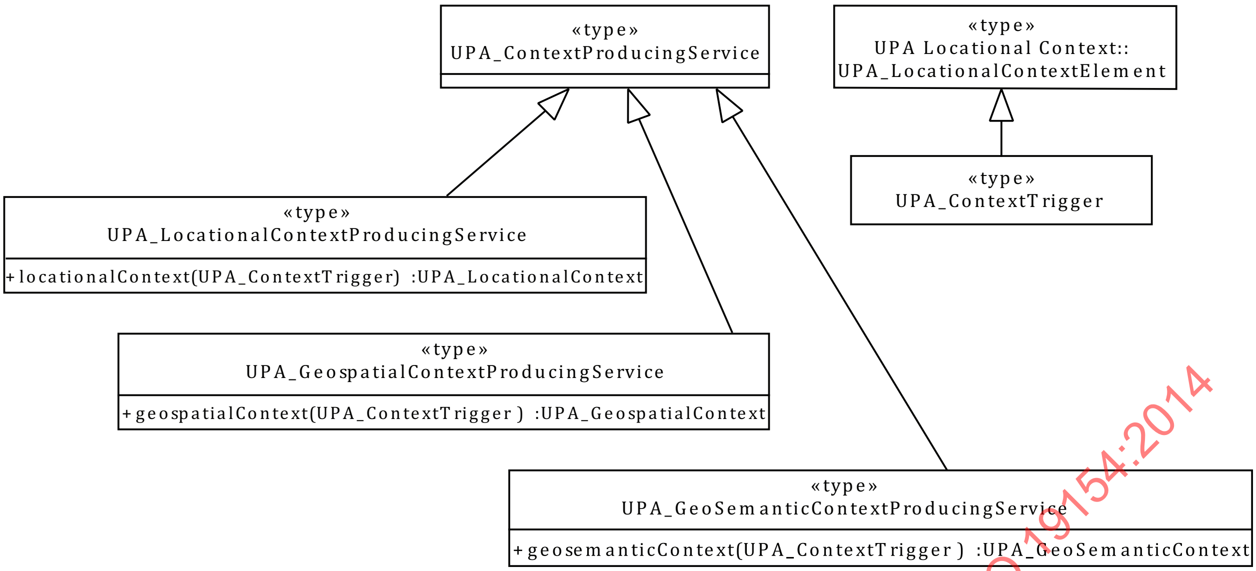

Figure 12 — UPA_ContextProducingService associations

7.3.2.2 Type — UPA_ContextTrigger

The type UPA_ContextTrigger, shown in Figure 13, is a class of any location representations for the user. All three types of contextual information, location, geospatial, and geosemantic context information, for the user shall be produced by this trigger.

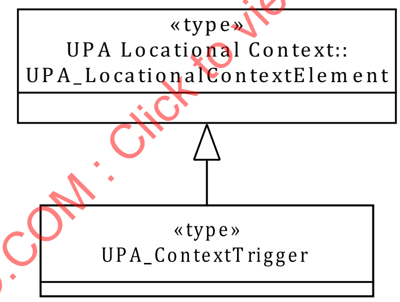

Figure 13 — UPA_ContextTrigger associations

7.3.3 Context Brokerage Service

7.3.3.1 Semantics

The UPA Context Brokerage Service provides services through a specific API for the UPA Context Producing Service to communicate with the other services such as LBS and a variety of geographic information services, as shown in Figure 14.

Any application service that requires UPA context information should access the UPA Context Brokerage Service. In addition, this service can hide the actual interface of various implementations of the UPA Context Production Service.

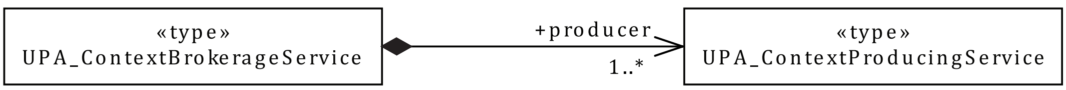

Figure 14 — UPA_ContextBrokerageService associations

7.3.3.2 Linked GeoData (LGD) service

The Linked GeoData (LGD) service is responsible for openly inter-connecting geographic information to external repositories or web resources using a transform to either Resource Description Framework (RDF) data or Web Ontology Language (OWL) ontologies.

The UPA LGD Context has aggregation roles from the UPA Context Information Model that consists of UPA Location Context, UPA Geospatial Context, and UPA GeoSemantic Context. The LGD Context specifies the use of an RDF triples mechanism (Subject, Predicate, and Object) for linking to various open data sets, such as Linking Open Data, GeoNames [14], or FOAF profiles for example.

7.3.3.3 Type — UPA_LGDService

The type UPA_LGD Service, as shown in Figure 15, provides services through a specific API for various functions such as transforming to RDF, cataloguing on LGD, registering on LGD stores, and quality control of LGD.

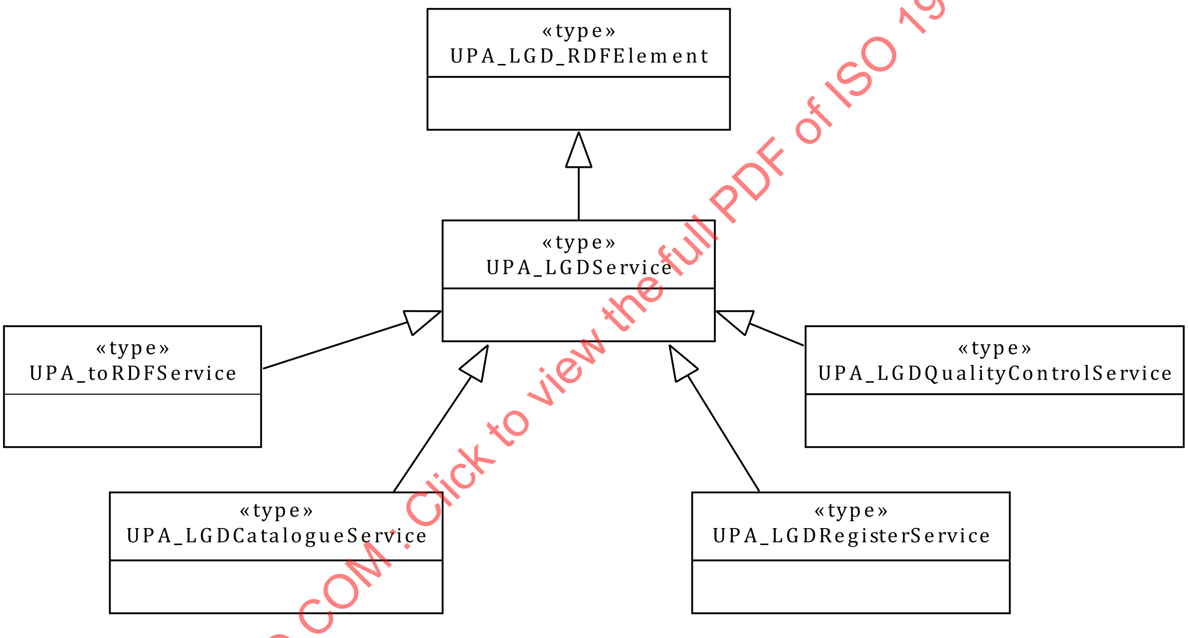

Figure 15 — UPA_LGDService associations

The LGD_RDFElement generalizes all four services under UPA_LGD Service, which is a class of any RDF data sets to be generated by the public users.

One of the detailed services, UPA_toRDF Service, transfers UPA data sets to RDF data and UPA_ LGDCatalogue Service provides catalogues of transformed RDF data. LGDRegister Service and LGDQuality Control Service control the quality of geographic information that is registered in LGD stores by public users.

Annex A
(normative)

Abstract test suite

A.1 Scope in UPA-to-GI standards

The test for scope in a UPA-to-GI standard is as follows.

a) Test purpose: Verify that the scope of the UPA-to-GI standard defines which aspects of geographic information it standardizes with respect to the list of aspects specified in Clause 1. For aspects that are not listed in Clause 1, verify that justifications are provided.

b) Test method: Inspect the scope of the UPA to geographic information standard or profile and identify which aspects of Clause 1 it refers to or the justifications for all additional aspects.

c) Reference: Clause 1.

d) Test type: Basic test.

A.2 Conceptual formalism

The test for the applicable conceptual formalism is as follows.

a) Test purpose: Verify that the conceptual formalism used in the standard is object oriented.

b) Test method: Inspect that the concepts in the standards are defined consistently with the object-oriented methodology.

c) Reference: 6.4.

d) Test type: Basic test.

A.3 Data conformance

Data conformance of a specification or standard adhering to this International Standard shall require the use of standard data types, where appropriate, in the activities being standardized.

a) Test Purpose: Verify the use of basic data types. When a data element is or requires the use of one of the following types, the implementation of that element or element component shall be an instantiation of a subtype of the corresponding type as defined in this International Standard.

b) Test Method: Inspect to ensure that the documents exhibit and explicitly state the required correspondence.

c) References: 7.2.

d) Test Type: Capability.

A.4 Service conformance

Service conformance of a specification or standard adhering to this International Standard shall require the use of standard service types, where appropriate, in the activities being standardized.

a) Test Purpose: Verify the use of basic services. When a service is or requires the use of one of the following services, the implementation of that service or service component shall be an instantiation of a subtype of the corresponding service defined in this International Standard.

b) Test Method: Inspect to ensure that the documents exhibit and explicitly state the required correspondence.

c) References: 7.3.

d) Test Type: Capability.

Annex B
(informative)

Additional background information on UPA-to-GI

B.1 Introduction

Annex B provides background and additional informative content on the subject of UPD-to-GI.

B.2 Need for a reference model

With the advancement of telecommunications technology, ever more powerful mobile devices, and rapid advances in web technologies, the general public are accessing and using many varieties of services, and many of those services make use of, or are exclusively focused on, geographic information. The users however, might not recognize that a specific service is using geographic information, due to the nature of presentation, or actual content used. Therefore, the public might be using geographic information services without actually being aware of it.

Many services have a geographic component, even though they are not specifically “map or location” applications. Some examples of these types of services are map or navigation assistance services found on many smart phones. Other examples are geo-tagging applications for posting pictures or movies, captured by the user, in a blog entry from their devices or tweeting from places where they have visited. Highly developed user application interfaces make these services very simple to use and many of them offer advanced functionality, with the general public being the primary user group for many of these applications. The general public, as users, are not only acting as consumers of geographic information, but also as producers of geographic information, creating various types of content and embedding that content with geographic information, then sharing that content with others.

The situation described here would not be possible without recent advances in ubiquitous computing technologies such as seamless mobility, context awareness, sensor networks, and cloud computing based system. These technologies are helping to foster the emergence of applications and services for what is referred to as ubiquitous public access to geographic information (UPA-to-GI).

The changing pace of the inter-related technologies described above, and the cross-domain linkages which exist between them, represent an immediate need for a reference model to define and clarify the concepts of UPA-to-GI.

B.3 Concepts of UPA-to-GI

This UPA-to-GI reference model presented here provides a conceptual framework defining how the domains of ubiquitous computing and geographic information are interconnected in terms of the logical environment for a set of applications and processes within each domain, a taxonomy of terms, and an ontology defining the applications and services.

There are two driving forces behind UPA-to-GI; they are the standardization of geographic information systems/services that enables end-users (professionals and laymen alike) to have access to the geographic information of their interest in an easy yet interoperable manner and the progress of ubiquitous computing technologies that results in an augmented and intelligent information infrastructure.

From a semantic point of view, the following three concepts help to clarify UPA-to-GI:

— ubiquity;

— public access;

— ubiquitous public access.

B.4 Ubiquity

Ubiquity, or omnipresence, is "the property of being present everywhere".

Using a similar construct, ubiquitous geographic information is "geographic information supplied in every place at any time for any device".

Ubiquity of geographic information is realized in a ubiquitous computing environment where end-users can make use of varied geographic information services based on "ambient intelligence", which is embedded, context-aware, personalized, adaptive, and anticipatory.

To address the issue of ambient intelligence for geographic information, the following methods may be used:

— seamless mobility/seamless access;

— geographic context awareness.

Regarding seamless mobility, the goal of embedded systems and technologies in a ubiquitous computing environment is to achieve a state of "seamless mobility" that provides mobile users with continuous and intuitive access to various information sources/services, including geographic information services, regardless of protocols, networks, bands, and the physical environment.

Geographic context awareness may be described from the standpoint of context awareness. One of the crucial characteristics of ambient intelligence is context-awareness for a variety of machines/agents/devices which belong to the end-users. Context-awareness is the integrated process or activity to collect and deliver context specific information, and convert it to tailored data for each user. The context may include identity, time, activity, and the location of the user. Once the geographic context of a user is extracted, information services are able to provide a rich and high quality of ambient intelligence to the user. The geographic context may include one's individual context, such as location, speed, and orientation. In addition, the content may be static, such as basic geographic information, or dynamic, such as weather and traffic conditions, or data from some kind of monitoring sensor.

B.5 Public access

Public access to geographic information means easy access or open access to geographic information sources and/or services by general public users and professional users alike. Greater emphasis is placed on the ease-to-use of geographic information services for the general public.

An important aspect of public access to geographic information is that public users are no longer passive consumers of geographic information but actively participate in the entire life cycle of geographic information from the production, distribution, and sharing of geographic information to the consumption.

Any request from users for any type of geographic information services such as LBS, map display, and so on may be unambiguously specified using the universal feature model specified by ISO 19109. This enables easy access for users to geographic information services since the users only need to specify what kind of features they want to see in a computerized environment, without knowing their structures or abstraction models, in order to obtain geographic information or geographic information services. This may be referred to as universal representation of the real world as based on the ISO 19109 feature model.

Another method of public access is through Linked Data. Linked Data is about using the Web to connect related data that wasn't previously linked, or using the Web to lower the barriers to linking data currently linked using other methods. The Linking Open Data (LOD) movement was initiated by the W3C Semantic Web Education and Outreach Interest Group promotes Linked Data.

Linked Data is also known as Linked GeoData when geographic information is involved. Linked GeoData can be defined and created by the general public along with the ever growing, publicly available open geographic data and information sources such as the Open Street Map [http://www.openstreetmap.org] project and other participatory and community data creation efforts.

Annex C
(informative)

Open Distributed Processing (RM-ODP) for UPA-to-GI reference model

C.1 Introduction

This International Standard defines a reference model for ubiquitous public access to geographic information (UPA-to-GI) using the viewpoints based on the model specified in ISO 19101-1:2014 and RM-ODP system architecture approach described in ISO/IEC 10746. The purpose of this architecture is to provide a description of the system from multiple viewpoints. This architecture helps to ensure that each viewpoint will be consistent with the requirements and with other viewpoints.

C.2 Application of RM-ODP viewpoints

Table C.1 describes how the RM-ODP viewpoints are applied in this International Standard.

Table C.1 — Application of RM-ODP Viewpoints in this International Standard

Viewpoint Name	Definition of RM-ODP viewpoint	Use of the viewpoint in this International Standard
Enterprise viewpoint (7.1)	A viewpoint on an ODP system and its environment that focuses on the purpose, scope, and policies for that system	This view identifies enterprise objects that specify different roles in the UPA-to-GI environment.
Information viewpoint (7.2)	A viewpoint on an ODP system and its environment that focuses on the semantics of information and information processing.	This view describes semantics and requirements for the processing of UPA service information using UML schema definitions.
Computational viewpoint (7.3)	A viewpoint on an ODP system and its environment that enables distribution through functional decomposition of the system into objects which interact at interfaces.	This view describes the functionalities of a UPA service/system using UML operation definitions.
Engineering viewpoint (Annex D)	A viewpoint on an ODP system and its environment that focuses on the mechanisms and functions required to support distributed interaction between objects in the system.	This view describes UPA-to-GI service architecture which consists of services, providers, brokers, and interfaces.
Technology viewpoint	A viewpoint on an ODP system and its environment that focuses on the choice of technology in the system.	Technology neutral

Annex D
(informative)

Service architecture for UPA-to-GI

D.1 Introduction

Annex D provides a short description of the conceptual service architecture for ubiquitous public access to geographic information (UPA-to-GI). This architecture is based on the services defined in ISO 19119—[4].

D.2 Conceptual service architecture

Figure D.1 presents the conceptual service architecture for ubiquitous public access to geographic information (UPA-to-GI). The grey coloured items are identified as standardization areas.

The UPA-to-GI service architecture consists of services, providers, brokers, and interfaces. The service manager is responsible for linking the primary components of the UPA services.

These primary components are the geographic context awareness service, seamless access service for heterogeneous mobile environments, linked geodata service for various open data sets as RDF on the Web, and public geodata registration and quality control service for user generated contents.

4) To be published.

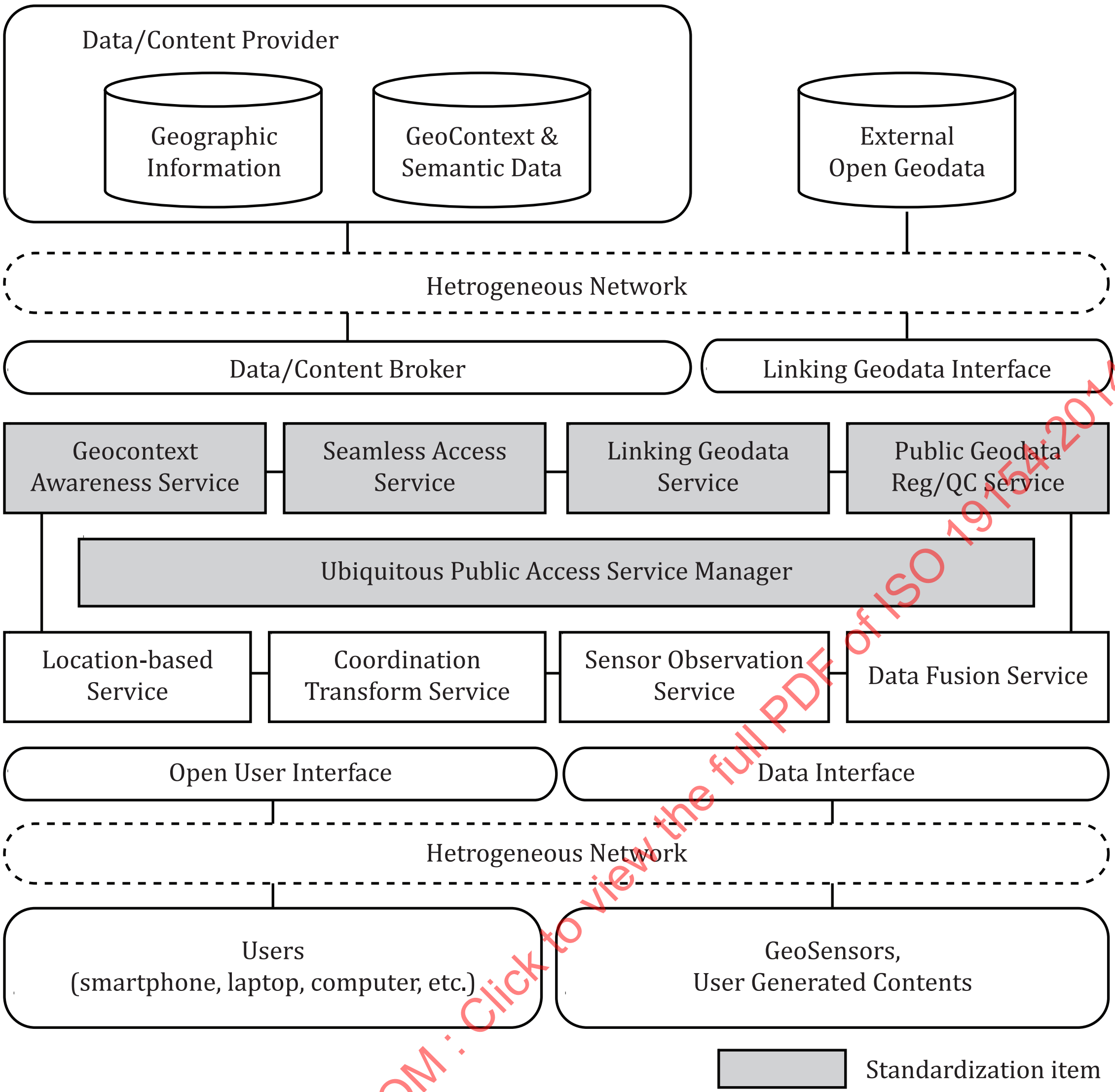

Figure D.1 — UPA-to-GI Service architecture

The data/content provider collects implicit geographic contents with current geographic information, and delivers to the service manager through data broker for being disseminated to appropriate services.

The linked geodata interface could further join UPA services external web services, such as Geonames Linked GeoData[13], and extend the web by setting RDF links between geographic-related items from different sources.

D.3 Service flow for UPA-to-GI

It is possible for these services to be accessed by heterogeneously networked devices, such as smart-TVs, laptop computers, PDAs, mobile phones, and other networked devices. These services should be provided in a similar manner to the heterogeneous clients, which can make their connections to the network, and then take on any form.

The service manager for satisfying a user's requirement should effectively exchange information as a message and data-flow between the service and the user's client. There is also a user service interface between the user clients and the service manager. This user interface enables interaction with user requests via services, and receives user queries and passes them to the service manager which distributes the request to the proper service.

All requests from services should be encapsulated in a request-response manner. The particular condition for a client or service might be stored either at the client-side or the server-side, and identified by the state variables if needed.

This architecture should be satisfied with diverse network types, such as LAN, Cable Modem, ADSL, WiFi, Zigbee®[5)], Bluetooth®, and could include additional mobile environments including pedestrian, in-car, public transportation, etc. This service architecture could provide UPA services for data-roaming to seamless access services anywhere or any time.

In addition, an interface for collecting data could link various geographic events captured from a geosensor with user generated contents or current information. These collected data sets could then be bound to a suitable service via a data fusion service or sensor observation service.

5) Zigbee® and Bluetooth® are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO 19154 of these products.

Annex E
(informative)

Existing standardization efforts

E.1 Standardization areas

E.1.1 Introduction

Annex E examines various areas where current and forthcoming standardization efforts will benefit and extend the domain of UPA-to-GI.

These areas are divided into the following categories:

— standards to allow public access to users (E.1.2);

— standards to manage geographic information for public access (E.1.3);

— standards to incorporate ubiquitous technologies into public access (E.1.4).

E.1.2 Standards to allow public access to users

A number of ISO/TC 211 standards already belong to this category; however, they are focused on the public consumption of geographic information.

In order for the concept of UPA to expand, service standards not only for public consumption but also for the public production of geographic information are needed.

E.1.3 Standards to manage geographic information for public access

The standards for the production and management of geographic information belong to this category. As geographic information produced by public users could have accuracy and consistency issues, more rigorous specifications and standards for data quality and metadata are required for this type of geographic information.

In order to integrate multiple sources of geographic information, standards for global identifiers are also needed.

E.1.4 Standards to incorporate ubiquitous technologies into public access

Context-awareness is an essential function not only for ubiquitous computing but also for public access to geographic information. Spatial awareness, a type of context-awareness, is particularly important for UPA.

Spatial awareness is no longer limited to a UPA service that provides only user-interfaces; spatial awareness is an important function of any kind of pervasive computing device.

Massively distributed architectures of ubiquitous computing and associated middleware are important areas to be considered for standardization in UPA.

E.2 Standardization efforts related to UPA-to-GI

Figure E.1 visually portrays the types of standardization efforts that are taking place in terms of UPA context information model defined in 7.2.2.

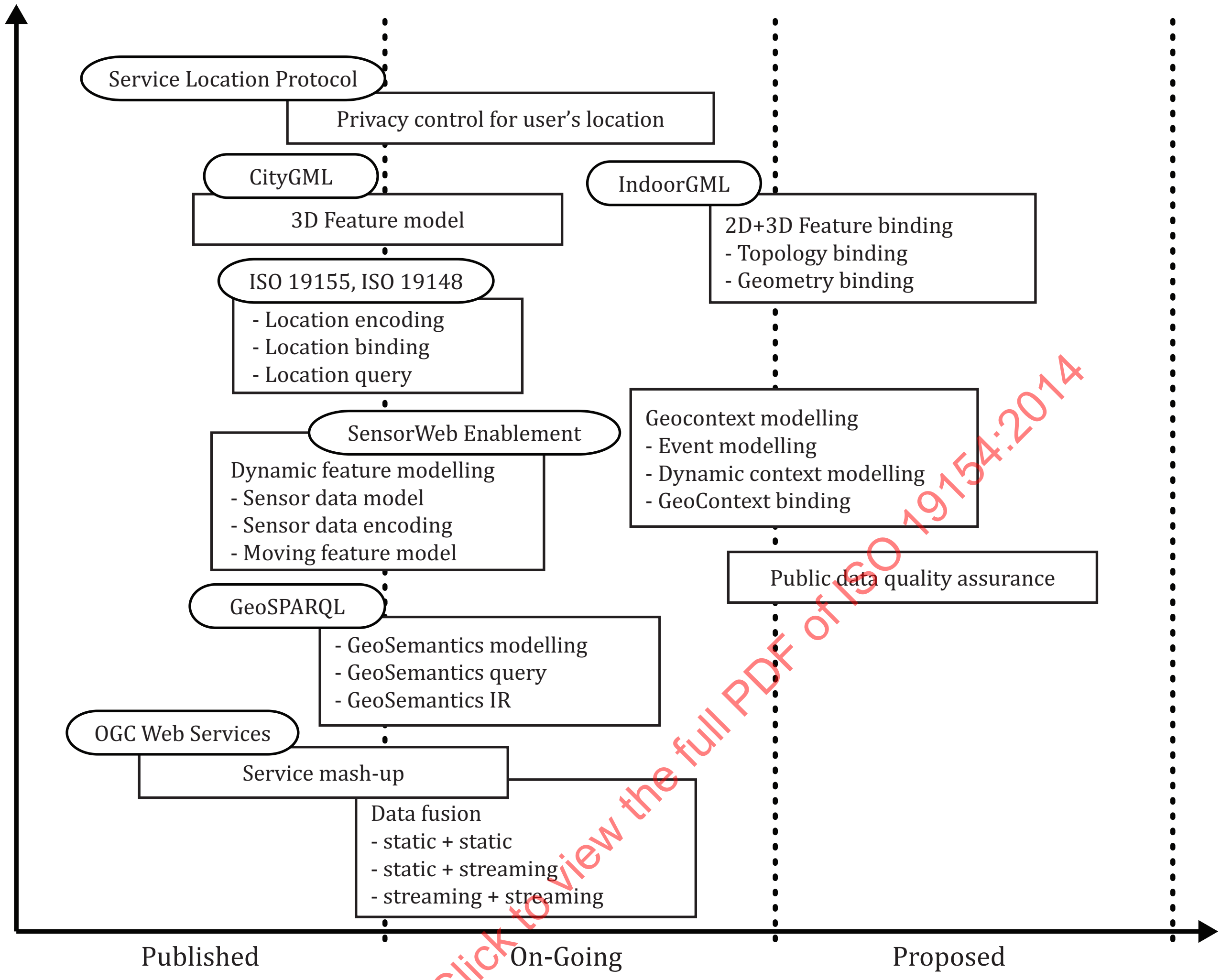

Figure E.1 — Standardization efforts related to UPA context information model

The requirements for UPA standards are not only limited to ISO/TC 211 but also related to other domains and standardization organizations.

The harmonization with other related standards should be an important priority for the standardization of UPA.

Table E.1 provides a summary of related standards having a direct link to UPA. While this list is not exhaustive, it does provide information on the more well-known and implemented standards within the various geomatics communities.

Table E.1 — UPA related standards

Category	Standard	Standard description	Origin
Privacy control for a user's location	Service Location Protocol	Service location protocol describes architecture for privacy-preserving location-based services in the Internet, focusing on authorization, security, and privacy requirements for the data formats and protocols used by these services.	IETF (Internet Engineering Task Force)
	Access Control and Terms of Use	Access control and terms of use (discussion paper) demonstrates a number of functional capabilities related to rights management (Access Control and Terms of Use) that need to be described and chained.	Open Geospatial Consortium (OGC)
Multi-dimensional feature modelling and representation	CityGML	Encoding Standard for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML is implemented as an application schema of the Geography Markup Language version 3.1.1 (GML3). CityGML models both complex and georeferenced 3D vector data along with the semantics associated with the data. In contrast to other 3D vector formats, CityGML is based on a rich, general purpose information model in addition to geometry and appearance information. For specific domain areas, CityGML also provides an extension mechanism to enrich the data with identifiable features under preservation of semantic interoperability.	Open Geospatial Consortium (OGC)
	IndoorGML (candidate)	The IndoorGML candidate standard will provide a framework of interoperability between systems and services for sharing indoor navigation information. Indoor navigation comprises routing planning, localization, and tracking of subjects and objects. IndoorGML will support these activities in different modes of locomotion, i.e. walking, driving, and flying as well as navigation in virtual environments. Since there is no unique localization technology like GPS available indoors, many different types of indoor positioning techniques are used today, often in combination with each other.	Open Geospatial Consortium (OGC)
	X3D, X3D mobile X3D Earth	X3D is a standard file format and run-time architecture to represent and communicate 3D scenes and objects using XML. X3D has a rich set of componentized features that can be tailored for use in engineering and scientific visualization, CAD and architecture, medical visualization, training and simulation, multimedia, entertainment, education, and more.	ISO/IEC JTC 1/SC 24/WG 6 Web3D Consortium
	OpenARML	ARML (augmented reality markup language) is a specification that allows content developers to create content that is displayed on various mobile AR browsers. Wikitude is the first browser that natively supports ARML. ARML is built on a subset of KML, a set of common tags supported across all browsers and some browser specific extensions. This specification describes the full set of tags supported by Wikitude.	AR Consortium
	Feature binding (under consideration)	Standards for Multi dimensional (e.g. 2D+3D) feature binding.	

Table E.1 *(continued)*

Category	Standard	Standard description	Origin
Location management	Place Identifier Architecture ISO 19155:2012	This standard specifies an architecture that defines a reference model with an encoding method for an identifier of a place. The concept of "place" includes "places" not only in the real world but also those in the virtual world. These "place" are identified using either coordinate identifiers, geographic identifiers, or virtual world identifiers such as URI. This standard is applicable to location-based services, emergency management services, and other application domains that require a common architecture, across specific domain, for the representation of place descriptions using coordinate, geographic, or virtual world identifiers.	ISO/TC 211 – Geographic information/ Geomatics
	Transfer nodes ISO 19147 (candidate)	Transfer Nodes includes bus stops, train stations, subway stations, ferry terminals, and airports. The nodes denote sites in transport networks where one can change modes or means of transportation. These nodes are of vital importance to make multi and inter modal travel planning work. Thus they are of vital importance to Intelligent Transportation Systems (ITS).	ISO/TC 211 –Geographic information/ Geomatics
	Geolocation API Specification (candidate)	This specification is limited to providing a scripting API for retrieving geographic position information associated with a hosting device. The geographic position information is provided in terms of World Geodetic System coordinates based on WGS84. The scope of this specification does not include providing any kind of mark-up language nor any definition of URI schemes for building URIs that identify geographic locations.	W3C (World Wide Web Consortium)
	Robotic Localization Service (RLS)	This standard defines specifications for representing and manipulating advanced location measurement results and related information both in static and dynamic manner. In order to achieve high precision or accuracy, modern location data estimation techniques require auxiliary information such as measurement time or error estimation. Aggregation of multiple measurement sources is often required for attaining high precision. RLS defines a framework for handling these information that are essential for advanced positioning by extending the existing spatial coordinate standards. Although the specification is named as 'robotic', this specification can be applied to other fields that require advanced location estimation, such as ubiquitous sensor networks or next-generation geographic information systems.	OMG (Object Management Group)
Dynamic feature modelling	Moving object snapshot (candidate)	This standard defines a GML application schema to encode a snapshot of a moving object including its location, translational velocity, and acceleration. This specification addresses the use case of a solid object, such as a car, travelling in a plane local to the object, such as a street. The velocity is an instantaneous vector composed of a scalar speed and a heading relative to North.	Open Geospatial Consortium (OGC)
	Sensor Model Language (SensorML)	Sensor Model Language Encoding Standard (SensorML) specifies models and XML encoding that provide a framework within which the geometric, dynamic, and observational characteristics of sensors and sensor systems can be defined. There are many different sensor types, from simple visual thermometers to complex electron microscopes and earth observing satellites. These can all be supported through the definition of atomic process models and process chains.	Open Geospatial Consortium (OGC)

Table E.1 *(continued)*

Category	Standard	Standard description	Origin
	RoSE (Representation of Sensory Effects) (candidate)	The aim of RoSE is to provide a standardized framework which shall allow for controlling sensory effects in order to increase the overall experience of the user when consuming multimedia content. A sensory effect is an effect to augment feelings by stimulating sensory organs in a particular sense of a multimedia application. Examples of sensory effects include, but are not limited to, audio (sound), visual (video), tactile (light, shading, vibration, wind, temperature, fog, and water), and olfactory (scent).	ISO/IEC JTC 1/ SC 29/W 11(MPEG)
	GeoSPARQL - a Geographic Query Language for RDF Data, v1.0	This standard defines an enhanced query language based on SPARQL that uses an RDF (Resource Description Framework) representation for geographic information based on the General Feature Model (from ISO 19109) and spatial predicates consistent with the spatial schema (from ISO 19107), and query predicates for geometric and topological operators (from Simple Feature, or ISO 19125).	Open Geospatial Consortium (OGC)
Geosemantics	Open Search geo extension (candidate)	The purpose of the OpenSearch-Geo extensions is to provide a standard mechanism to query a resource based on geographic extents, or location name. The geospatial results are based on the GeoRSS standards. Therefore, latitude/longitude order, bounding box parameters, and polygon are all using that standard.	OpenSearch.org
	Ontology – Part 1: Framework ISO/TS 19150-1 (candidate)	The semantic web has become an extension of the already existing web of data, by adding machine-processable data (with embedded semantics) as opposed to just documents. This approach involves reasoning capabilities based on ontologies. Ontology consists of a formal representation of phenomena of a universe of discourse with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships. The other proposed parts of ISO 19150 are: — Part 2: Rules for developing ontologies in the Web Ontology Language (OWL); — Part 3: Semantic operators, defining semantic proximity operators between concepts that complement geometric and temporal operators; — Part 4: Service ontology, identifying the framework for service ontology and defining the description of Web services for geographic information in an ontology language; — Part 5: Domain ontology registry, defining an international registry of geographic information domain ontologies and its maintenance; — Part 6: Service ontology registry, defining an international registry of geographic information service ontologies and its maintenance.	ISO/TC 211 – Geographic information/ Geomatics
	W3C Geospatial Vocabulary	This technical report defines a basic ontology and OWL vocabulary for representation of geospatial properties for Web resources.	W3C

