ETSI GS CIM 050 V1.1.1 (2024-11)

GROUP SPECIFICATION

Context Information Management (CIM); Aligning with geo-information

Reference

DGS/CIM-0050

Keywords

API, IoT, NGSI-LD

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI IPR online database.

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™**, **LTE™** and **5G logo** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) cross-cutting Context Information Management (CIM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Executive summary

The present document specifies how to make geodata accessible as Linked Data. It proposes changes and enhancements to ETSI GS CIM 006 [5] and ETSI GS CIM 009 [1].

Introduction

The present document is complementary to ETSI GR CIM 049 [i.21]. The use cases that ETSI GR CIM 049 [i.21] has documented show that many cities and communities use both geographical systems and NGSI-based systems and will continue in the future.

By further analysing the results and ideas of ETSI GR CIM 049 [i.21], which are derived from interviews with a large number of smart cities representatives, the present document recommends changes to ETSI GS CIM 006 [5] and ETSI GS CIM 009 [1].

1 Scope

The present document specifies how to make geodata accessible as Linked Data. It specifies how to share spatial (and spatio-temporal) data, and how to make them interoperable with, within, and between systems and territories. It also specifies how to both establish and maintain the number of connections between NGSI-LD Entities (see ETSI GS CIM 009 [1]) and their geographical 2D/3D representations.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or nonspecific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI GS CIM 009 (V1.8.1): "Context Information Management (CIM); NGSI-LD API".

[2] IETF RFC 7946: "The GeoJSON Format".

[3] OGC® GeoSPARQL: "A Geographic Query Language for RDF Data".

[4] ISO/IEC 12113:2022: "Information technology — Runtime 3D asset delivery format — Khronos glTF™ 2.0".

[5] ETSI GS CIM 006: "Context Information Management (CIM); NGSI-LD Information Model".

[6] OGC®: "OGC Name Type Specification - Definitions - part 1 - basic name".

[7] OGC® RAINBOW: "Collections".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or nonspecific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] W3C®: "Universal Resource Identifier (URI)".

[i.2] Eric Evans, Addison-Wesley Professional, 2003: "Domain-Driven Design (DDD): Tackling Complexity in the Heart of Software".

[i.3] Open Agile Architecture™, Part 2: The O-AA Building Blocks: "Domain-Driven Design: Strategic Patterns".

[i.4] Open Geospatial Consortium Inc. OGC® 06-103r4: "OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 1: Common architecture".

[i.5] FIWARE, IUDX, TM Forum, OASC and others: "Parking Smart Data Model".

[i.6] Digital Twin® Consortium: "Digital Twin definition".

[i.7] OGC®: "Geography Markup Language (GML)".

[i.8] OGC®: "CityGML".

[i.9] OGC®: "CityJSON".

[i.10] OGC®: "IndoorGML".

[i.11] OGC®: "API - Features - Part 1: Core".

[i.12] OGC®: "API - Features - Part 2: Coordinate Reference Systems by Reference".

[i.13] OGC®: "Coordinate Transformation Service.

[i.14] W3C®: "Time Ontology in OWL".

[i.15] Building Smart: "IFC Industry Foundation Classes 4.0.2.1: Version 4.0 - Addendum 2 - Technical Corrigendum 1".

NOTE: Published also as ISO 16739-1:2018.

[i.16] Interoperable Europe Programme: "GeoDCAT-AP".

[i.17] EC DG JRC Unofficial Draft 31 May 2024: "DCAT-AP-JRC - Version 2".

[i.18] ETSI GR CIM 048 (V1.1.1): "Context Information Management (CIM); Handling of data catalogues and data services with NGSI-LD".

[i.19] ETSI DGR/CIM-0055: "Context Information Management (CIM); Handling of services execution in NGSI-LD based systems".

[i.20] ArcGIS - ESRI.

[i.21] ETSI GR CIM 049: "Context Information Management (CIM); Usage of geo-information".

[i.22] Filip Biljecki, Hugo Ledoux, and Jantien Stoter: "An improved LOD specification for 3D building models". Computers, Environment and Urban Systems, 59: 25–37, 2016.

[i.23] ISO 7817-1:2024: "Building information modelling — Level of information need, Part 1: Concepts and principles".

[i.24] ISO 19650-1:2018: "Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling, Part 1: Concepts and principles".

[i.25] W3C®: "Building Topology Ontology", Draft Community Group Report 28 June 2021.

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AI Artificial Intelligence
AP Application Profile

NOTE: Part of DCAT-AP.

API Application Programming Interface
AP-JRC Application Profile – Join Research Center

NOTE: Part of DCAT-AP-JRC.

AR Augmented Reality
BIM Building Information Modelling
CAD Computer Aided Design
CityGML City Geography Markup Language
CRS Coordinate Reference System
DCAT Data Catalog vocabulary
DDD Domain Driven Design
EU European Union
GIS Geographic Information System
glTF gl Transmission Format
GML Geography Markup Language
GNSS Global Navigation Satellite System
GPS Global Positioning System
GPU Graphic Processing Unit
HTML HyperText Markup Language
HTTP HyperText Transfer Protocol
HVAC Heating Ventilation Air Conditioning
ID IDentifier
JSON JavaScript Object Notation
KML Keyhole Markup Language
LD Linked Data
LOD Level Of Details
LOIN Level Of Information Need
NGSI Next Generation Service Interfaces
NGSI-LD Next Generation Service Interface - Linked Data.
OGC Open Geospatial Consortium
OWL Web Ontology Language
QGIS Quantum Geographic Information System
RDF Resource Description Format
SPARQL SPARQL Protocol And RDF Query Language
SQL Standard Query Language
TTL Terse RDF Triple Language

NOTE: Pronounced "turtle".

URI Uniform Resource Identifier
URL Unified Resource Locator
VR Virtual Reality
WGS World Geodetic System
WKT Well-Known Text
XML eXtensible Markup Language
XSD eXtensible markup language Schema Definition

4 Recommendations derived from ETSI GR CIM 049

4.1 Lessons learned from the analysis of use cases documented in ETSI GR CIM 049

The use cases that ETSI GR CIM 049 [i.21] has documented show that many cities and communities use both geographical systems and NGSI-based systems and will continue in the future. Several of those use cases require some level of interoperability between geographical software components and NGSI ones.

The interoperability needs can be illustrated by two simple examples:

- A city would like to provide a service enabling a citizen or tourist to indicate a geographical location and obtain a list of events (e.g. a concert, an exhibition, etc.) to which he or she could join. The list of events and their description is managed by a Context Broker that implements a Cultural Events Smart Data Model.

- The team that manages the gardens using an application that implements a Garden Smart Data Model needs to access garden information contained in the geographical system and keep that information consistent in both systems. For example, the geographical system using some AI capabilities identifies that a tree has died. The garden team needs to be informed to take care of the dead tree.

For practical reasons as well as economical ones, it would not make sense to (re)-develop cultural events management use cases in the geographical system or (re)-develop geographical mapping features in the garden management system.

The OGC/NGSI interoperability initiatives that were analysed such as the OGC incubator or the Civitas Connect initiative are developing NGSI-LD domain models that mirror the corresponding OGC models (i.e. a Battery model for Civitas Connect and an airport facility model for the OGC incubator). This type of approach does not meet all the needs of the use cases have been analysed. It is not only needed to specify how to translate from one domain model to another (static view), but it is also needed to specify how to model the behaviour of a composite system (e.g. a city digital twin [i.6]) made of heterogenous subsystems (dynamic view).

On the static side, OGC models can be represented as Domain-Specific Ontologies. The potential loss of semantic information results from the fact that NGSI-LD API does not support sub-typing of Entity Types.

On the dynamic side, providing that both OGC and NGSI-LD support a subscription functionality, it is possible to implement the type of interactions that Local Digital Twin need to model. However, additional features need to be added to the NGSI-LD specifications and new modelling practices need to be adopted.

Some cities are using the transition to digital twins as a way of breaking out from the siloed way they operate. They are creating cross-functional working groups dedicated to the development and operation of digital twins. This organizational evolution is necessary to effectively manage the new types of interactions demanded by digital twins.

4.2 Topics from ETSI GR CIM 049 and associated standards or technologies

4.2.1 The 10-minute city

The key issues highlighted in ETSI GR CIM 049 [i.21] focus on data quality and the pathfinding algorithms within the applications. While NGSI-LD doesn't directly address the algorithms used in routing apps, it plays a crucial role in ensuring the data behind those routes is timely and accurate. By leveraging the observedAt, createdAt, or modifiedAt properties in an NGSI-LD response, people can deliver the real-time, reliable data that great routing depends on. Implementors are reminded to refer to ETSI GS CIM 009 [1], clause 6.3.11.

Recommendation: add the following note in a future revision of ETSI GS CIM 009 [1], clause 4.8, to help the implementors meet the objectives on the data quality timeliness of the system generated Temporal Attributes: NOTE: Implementors are recommended to request the TemporalProperty values when the timeliness of the data is an important data quality criteria for their use cases. For example, in case of HTTP binding, see ETSI GS CIM 009 [1], clause 6.3.11.

4.2.2 Underground Utilities Networks

Simple graph network representations with 2D or 3D polylines, using OGC Features for the components, are usually enough to represent and share context information for utilities networks.

When dealing with underground artefacts, the elevation (depth) of the artefact can be specified using a GeoJSON geometric object that includes altitude as specified in IETF RFC 7946 [2] and quoted in the present document in italics as follows:

"A position is an array of numbers. There MUST be two or more elements. The first two elements are longitude and latitude, or easting and northing, precisely in that order and using decimal numbers. Altitude or elevation MAY be included as an optional third element".

EXAMPLE: { "type": "Feature", "geometry": { "type": "Point", "coordinates": [12.4924, 41.8902, 50] } }

Again in GeoJSON [2], "*An OPTIONAL third-position element SHALL be the height in meters above or below the WGS 84 reference ellipsoid. In the absence of elevation values, applications sensitive to height or depth SHOULD interpret positions as being at local ground or sea level"*.

For the components of the utilities' networks, the ETSI SAREF ontology (https://saref.etsi.org) provides the necessary complement to the NGSI-LD API and could be extended when needed.

Due to the large scale of these networks and the needed precision, geo-localized coordinates are normally used, and the NGSI-LD Cross Domain Information Model [5], as well as the NGSI-LD API [1], answer the need, **provided that a CRS is added to them, as specified in clause 6.2**.

Recommendation: add a CRS property to the Cross Domain Information Model [5] and API [1].

4.3 Disaster and emergency

4.3.0 Foreword

The ability to share data with precise geospatial references in 2D and 3D with higher refresh intervals is important. Because disasters and emergencies always trigger a "crisis mode", it may be useful that the requirements on subscriptions related to crisis events can be defined and tested in advance and be ready to be instantiated in the context broker when an alert is raised.

The "isActive" member of a subscription enables this capability, as described in Table 1, which is extracted from Table 5.2.12-1 of ETSI GS CIM 009 [1].

Table 1: isActive member description

isActive	Boolean	*true* by default	0..1	Allows clients to temporarily pause the subscription by making it inactive. *true* indicates that the Subscription is under operation. *false* indicates that the subscription is paused, and notifications shall not be delivered.

The description in Table 1 might be clearer to the users of the NGSI-LD API if the fact that a *paused* subscription does not execute any queries is added in the description, for example by changing it as follows:

Allows clients to temporarily pause the subscription by making it inactive. true *indicates that the Subscription is under operation.* false *indicates that the subscription is paused,* ***associated queries shall not be executed****, and notifications shall not be delivered.*

More importantly, in Table 5.2.14.1-1 of ETSI GS CIM 009 [1], NotificationParams.endpoint cardinality is "1", indicating that the notification is sent to only one endpoint. The proposal is to change it to "1..*" to dispatch the same information to various endpoints, instead.

Recommendation: further study the opportunity to modify the NotificationParams.endpoint cardinality from "1" to "1..*" in Table 5.2.14.1-1 of the NGSI-LD API [1].

4.3.1 Challenge of defining regions of interest

In order to define a location, cities are using both geometries with precisely defined geospatial coordinates and/or geographical names. The OGC standards, allow Locations to be defined by a geometry object like a point, a polygon, a polyline, a set geometry, but also with a name and a URI [i.1] which identify the Location, as shown in Table 2, extracted from section 7.12 of release 3.0.0 of GeoDCAT-AP [i.16].

In ETSI GS CIM 009 [1] and ETSI GS CIM 006 [5] the geographic location (GeoProperty) is defined as a coordinate-based location. It is useful, to meet the requirements of the smart cities, to add support to "named locations", similarly to what is specified by the GeoDCAT.

Table 2: Location entity of GeoDCAT (source [i.16] version 2.0.0)

+gazetteer	skos:inScheme	skos:ConceptScheme	This property *MAY* be used to specify the gazetteer to which the Location belongs.	0..1
+geographic identifier	dct:identifier	rdfs:Literal	This property contains the geographic identifier for the Location, e.g. the URI or other unique identifier in the context of the relevant gazetteer.	0..n
+geographic name	skos:prefLabel	rdfs:Literal	This property contains a preferred label of the Location. This property can be repeated for parallel language versions of the label - see § 9. Accessibility and Multilingual Aspects.	0..n
geometry	locn:geometry	rdfs:Literal typed as gsp:wktLiteral or gsp:gmlLiteral	This property associates any resource with the corresponding geometry.	0..1

The GeoDCAT-AP [i.16] does not say anything about the simultaneous usage of geometry, bbox, centroid or names to define the location, whereas the DCAT-AP-JRC [i.17] specifies that the Location has to be defined either by a name or by a geometry, but not both.

For NGSI-LD the choice of following the DCAT-AP-JRC [i.17] recommendation of using either names or geometry is to be evaluated with the NGSI-LD philosophy. Allowing simultaneous usage of the names and the geometries will simplify the processing of data as there is no need for an extra query to a geoname server to get the geometry associated with the identifier.

It can be noted that, as proposed in ETSI GR CIM 048 [i.18], attaching an identifier to the location may let infer that Location becomes an Entity. However, this identifier being "optional", it makes sense to keep location as a Property in NGSI-LD and call this identifier "geographic-identifier".

There are 4 options to implement named locations:

- Domains are free to define Location as an entity and include named location members in addition to NGSI-LD location GeoProperty in the entity. This was the initial proposal from the DCAT mapping:
  - PRO: no impact on NGSI-LD API.
  - CONS: different domains will end up having different ways to specify named locations.

- The NGSI-LD Cross Domain defines a Location entity which includes named location in addition to the location GeoProperty:
  - PRO: minimal impact on NGSI-LD API, no change on the location GeoProperty.
  - CONS: it adds an Entity in the Cross Domain when the philosophy seems to limit Entities specified by the API.
    The geographic identifier in the GeoDCAT is an optional member, which means that the Entity will have 2 identifiers: a mandatory ID and an optional geographicIdentifier.
- The NGSI-LD location GeoProperty is modified to include an optional named location and have the coordinates-based GeoProperty optional. (This option can be used for the DCAT mapping):
  - PRO: can be re-used by all domains.
  - CONS: will have an impact on the API as the geometry becomes optional.
- New Properties "*geographicIdentifier*" and "*gazetteer*" shown in Table 3 and "*geographicName*" shown in
- Table 4 are added to the Cross Domain Ontology [5], and they are used from API [1] as Properties of an Entity:
  - PRO: can be re-used by all domains.
  - CONS: generates a more complex mapping for the DCAT to NGSI-LD.

Table 3: geographicIdentifier and gazetteer Properties description

geographicIdentifier	String		0..n	This property contains the geographic identifier for the Location, e.g. the URI or other unique identifier in the context of the relevant gazetteer.
gazetteer	String	Valid URI	0..1	This property is a sub property which *MAY* be used to specify the gazetteer to which the geographicIdentifier belongs.

Table 4: geographicName Property description

geographicName	LanguageMap	The EU Vocabularies Name Authority Lists shall be used for continents, countries and places that are in those lists; if a particular location is not in one of the mentioned Named Authority Lists, Geonames URIs shall be used.	0..n	This property contains a preferred label of the Location. This property can be repeated for parallel language versions of the label.

Recommendation: add support in ETSI GS CIM 009 [1] for a named location with 2 properties geographicIdentifier and geographicName.

4.4 The need to work at different scales

In order to accommodate the ability to manage different scales in the representation of geometric information, in a map application for example, the recommendation is to use the concept of "Level of detail" as defined in CityGML [i.8] with a JSON implementation. See clause 6.4.

Another topic related to scale is that when one wants to represent detailed object shapes, the source data normally uses cartesian coordinates with a local reference coordinate system (for example, this is the case in BIM software, or in geometries representing industrial product). In this case using a new "3DShape" Property for indoor locations geometries or CAD data would limit data transformations. See the proposed specification in clause 6.5.

Recommendation:

- Add a "lod" sub-property to the NGSI-LD GeoProperty specification in ETSI GS CIM 009 [1].
- Add a "3DShape" Property to the NGSI-LD Cross Domain Information Model ETSI GS CIM 006 [5].

4.5 Local Digital Twins

The Digital Twin Consortium [i.6] defines a Digital Twin as "*an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and fidelity*".

Figure 1 describes an example of local digital twin, which synchronizes the interactions between a live flooding map, parking operations and a smart building.

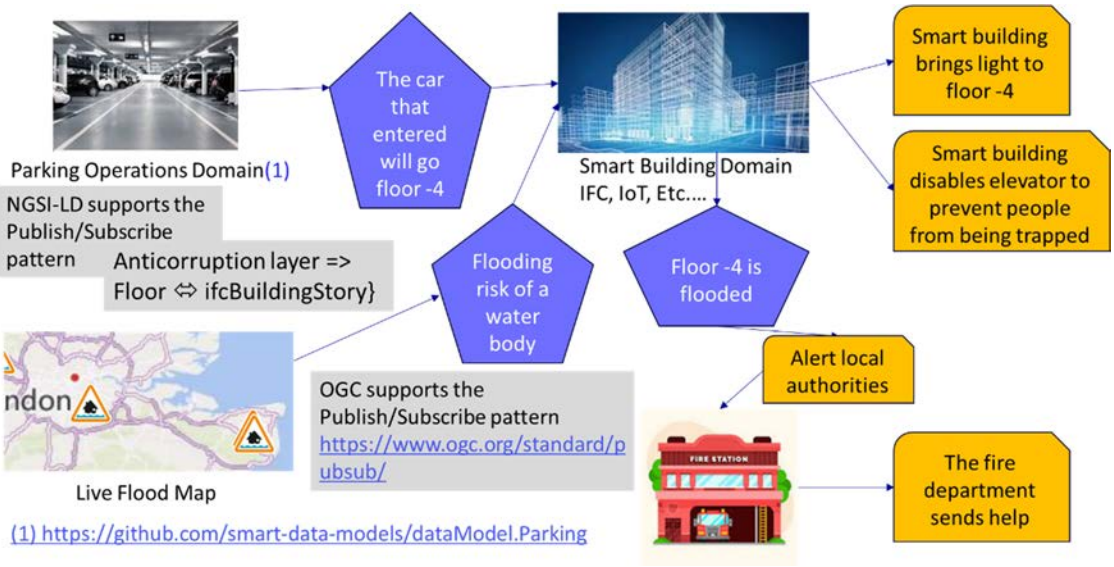

Figure 1: Local digital twin in Smart City

4.6 The challenge of data models

In an ideal world, there would be a single model spanning the whole domain of this digital twin. However, to maintain that level of unification is more trouble than it is worth, and it is not realistic in such an heterogenous world. In his book Domain Driven Design (DDD) [i.2], Eric Evans argues that it is necessary to allow multiple models to develop in the different parts of the system.

In the example in Figure 1, the digital twin combines a geographical model (flood map), with a parking smart data model [i.5] and a Smart Building model based on BIM data. The same real-world entity, for example "*floor minus 4*" is represented in the parking data model and in the smart building model.

The digital twin needs to know that when parking operations sends a car to floor -4, the smart building should turn on the light in that same floor and in the building where the parking is located.

4.7 Identifiers

This implies that though the parking operations system does not represent and identify that floor the same way as the smart building does, the digital twin needs to know that both sub-systems talk about the same floor. The real-world NGSI-LD Entity "Floor" is fundamentally defined by a thread of continuity and identity. The smart building software needs to know in which building and which basement to switch on the lights. The smart parking data model represents the concept of floor as a property of the OffStreetParking Entity Type. At the level of the digital twin, a mechanism needs to be designed to manage the identity of the real-world object "floor". The NGSI-LD Entity URI may not be sufficient outside of the scope of the Context Broker. Cross-model mapping mechanisms are likely to be needed to meet the real-world entity identification requirement.

4.8 Towards more sophisticated modelling techniques

Though the NGSI-LD subscription functionality provides an implementation mechanism that is useful to implement the behaviour of a digital twin, it shall be enriched. Entity-Relationship modelling needs to be extended with additional concepts fit to represent the behaviour of complex and heterogenous systems. The Bounded Context and Domain Event concepts from Domain Driven Design [i.3] are of great help to better deal with multiple models and to model their behaviour.

First the publish–subscribe pattern may not be implemented in each of the sub-systems in a way that meets the digital twin's interoperability requirements. Second, digital twins need to consider several factors such as latency, parallel execution, deadlock events, consistency, availability or partition tolerance. This requires using appropriate modelling techniques which are out of the scope of the present document but will be studied by the ISG CIM Work Item DGR/CIM-0055 [i.19].

4.9 Issues with software

GIS Software do provide OGC based interfaces. The recommendations in the present document have taken into account that the proposed concepts like CRS, LOD, 3DShape are already available within mainstream software and that interfaces or plugins are available to implement these concepts.

5 Geographic standards in scope

ETSI GS CIM 009 (V1.8.1) [1] includes the following geospatial concepts:

- Feature, FeatureCollection
- GeoProperty
- Location, CoordinateBasedLocation, GraphBasedLocation, SetBasedLocation
- Point, Polygon, LineString, MultiPoint, MultiLineString, MultiPolygon and GeometryCollection
- GeoQuery
- TemporalProperty, TimeInterval

These concepts are also defined by the following OGC standards:

- Geography Markup Language: Location, CoordinateBasedLocation
- GeoJSON: Feature, FeatureCollection, Point, Polygon, LineString, MultiPoint, MultiLineString, MultiPolygon and GeometryCollection
- IndoorGML [i.10]: GraphBasedLocation, SetBasedLocation
- Time Ontology [i.14] in OWL: TemporalProperty, TimeInterval
- GeoSPARQL [3]: GeoQuery

Real world use case sharing spatial (and spatio-temporal) data are based on a wider set of OGC standards, including OGC standards, Sensor data, Coordinate Reference Systems, GeoSPARQL, Tiles which can be considered as a GIS Domain.

6 Extending NGSI-LD

6.1 Method

There are several identified extension opportunities that have been analysed. Identified extension opportunities will be described and recommendations will be formulated.

For each opportunity 3 options will be examined:

- Definition of the model to be implemented in a domain model or smart data model.
- Extension of the Cross Domain Ontology with new or revised Properties or new Entities.
- Extension of the Cross Domain Ontology with mandatories Properties.

No new Entities to be added to the NGSI-LD Cross Domain Ontology have been identified.

New NGSI-LD properties related to the GIS domain in clause 6.2, "Level of Detail", "3DShapes" have been identified.

4 geoqueries functions to be added have been identified.

6.2 Information about GeoProperty, Coordinates and CRS

NGSI-LD uses the GeoJSON format, which in its current version (IETF RFC 7946 [2]) specifies the WGS84 Coordinate Reference System (CRS) as the only option. Since NGSI-LD specifies that geometry properties have to be GeoJSON objects, it inherently relies on WGS84.

The OGC API [i.11] supports two coordinate reference systems:

- WGS 84 longitude, latitude.
- WGS 84 longitude, latitude, ellipsoidal height.

However, OGC allows the use of other CRSs, including the necessary transformations (see: OpenGIS Coordinate Transformation [i.4]).

Interviews and sample analysis from the data.gouv.fr dataset reveal that in real-world implementations, CRS definitions are often missing, or datasets use a different CRS than stated in their data catalogue. This causes errors and requires manual intervention to redefine the CRS during data import or aggregation.

Several cities, such as Porto and Valencia, said they are required by law to use the CRS system mandated by their government.

There are valid reasons why WGS84 is not ideal as a global default CRS, primarily due to plate tectonics. WGS84 is fixed to the North American plate, so while it works well for that region, locations on other plates suffer from displacement, which increases over time (e.g. North America and Europe drift apart at 2,5 cm/year).

Due to WGS84's limitations in Europe, guidelines like INSPIRE recommend using ETRS89. Additionally, non-GPS GNSS systems do not use WGS84.

Different geospatial applications employ various coordinate systems, depending on system defaults, regional needs, local regulations, and export settings. OGC standards specify how to define the reference system used for geo-localized 2D or 3D point coordinates and how to handle these when reading the data. The standards also provide conversion rules to transform data between CRSs (see OGC Coordinate Transformation Service [i.13]). Additionally, repositories exist to define CRSs unambiguously.

6.3 coordRefSys subproperty

The present document proposes:

- The inclusion of a new CRS non-reified subproperty called "*coordRefSys*" in the GeoProperty.
- To request such a coordRefSys information in the linked dataset from other domain models.

The present document proposes to use the following definition (from OGC RAINBOW Collections [7]) for coordRefSys in a future new version of ETSI GS CIM 006 [5] (NGSI-LD Information Model):

```
"coordRefSys": "http://www.opengis.net/def/glossary/term/CoordinateReferenceSystemCRS"
```

The coordRefSys shall be given as a URL formatted according to the OGC Name Type Specification [6]:

```
http://www.opengis.net/def/crs/{authority}/{version}/{code}
```

where {authority} designates the authority responsible for the definition of this CRS (usually "EPSG" or "OGC"), and where {version} designates the specific version of the CRS ("0" (zero) is used if there is no version).

For instance, the Dutch national CRS in 3D is expressed as follows:

```
"metadata": {
  "referenceSystem": "https://www.opengis.net/def/crs/EPSG/0/7415"
}
```

It is important to note that the CRS should be a three-dimensional one, i.e. the elevation/height values should be with respect to a specific datum.

Formally, adding an optional coordRefSys member to the GeoProperty data type definition in a future revision of ETSI GS CIM 009 [1] is achieved as detailed in Table 5, which is extracted from Table 5.2.7-1 of ETSI GS CIM 009 [1]. See text in bold.

Table 5: NGSI-LD GeoProperty data type definition

Name	Data Type	Restriction	Cardinality	Description
type	String	It shall be equal to "GeoProperty"	1	Node type
value	JSON Object	As mandated by clause 4.7	1	Geolocation encoded as GeoJSON
coordRefSys	**String**	**Valid URI**	**0..1**	**CRS Reference** **When not specified, the WGS84 is the default**
datasetId	String	Valid URI	0..1	It allows identifying a set or group of property values
observedAt	String	*DateTime* (clause 4.6.3)	0..1	Timestamp. See clause 4.8
<Property name>	Property or Property[] (see note 1)	See datatype definition in clause 5.2.5	0..N	Properties of the `GeoProperty`
	GeoProperty or GeoProperty[] (see note 1)	See datatype definition in clause 5.2.7	0..N	`GeoProperties` of the `GeoProperty`
	LanguageProperty or LanguageProperty[] (see note 1)	See datatype definition in clause 5.2.32	0..N	`LanguageProperties` of the `GeoProperty`
	JsonProperty or JsonProperty[] (see note 1)	See datatype definition in clause 5.2.38	0..N	`JsonProperties` of the `GeoProperty`
	VocabProperty or VocabProperty[] (see note 1)	See datatype definition in clause 5.2.35	0..N	`VocabProperties` of the `GeoProperty`
	ListProperty or ListProperty[] (see note 1)	See datatype definition in clause 5.2.36	0..N	`ListProperties` of the `GeoProperty`

Name	Data Type	Restriction	Cardinality	Description
<Relationship name>	Relationship or Relationship[] (see note 2)	See datatype definition in clause 5.2.6	0..N	Relationships of the `GeoProperty`.
	ListRelationship or ListRelationship[] (see note 2)	See datatype definition in clause 5.2.37	0..N	`ListRelationships` of the `GeoProperty`.
NOTE 1: For each Property (or subclass of Property) identified by the same Property name, there can be one or more instances separated by `datasetId`.				
NOTE 2: For each Relationship (or subclass of Relationship) identified by the same Relationship name, there can be one or more instances separated by `datasetId`.				

The following examples illustrate practical usage.

EXAMPLE 1: Including CRS coordRefSys property in the GeoProperty.

```
{
  "@context": [
    "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
  ],
  "location": {
        "type": "GeoProperty",
        "value": {
             "type": "Point",
             "coordinates": [13.3698, 52.5163]
        },
        "coordRefSys": "https://www.opengis.net/def/crs/EPSG/0/7415"
  }
}
```

EXAMPLE 2: Including coordRefSys property in the concise GeoProperty.

```
{
  "@context": [
    "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
  ],
  "location": {
        "value": {
             "type": "Point",
             "coordinates": [13.3698, 52.5163]
        },
        "coordRefSys": "https://www.opengis.net/def/crs/EPSG/0/7415"
  }
}
```

NOTE: **This cannot be rendered in simplified representation without losing the CRS information**.

6.4 Level Of Detail

6.4.1 LOD

CityGML's Levels Of Detail (LOD) are designed for the multi-scale approach to 3D modelling. With four levels (0 through 3), each step adds more depth, precision, and richness to how objects are visualized in 3D, as shown in Figure 2. As the LOD increases, so does the refinement of the geometry, making each representation more detailed.

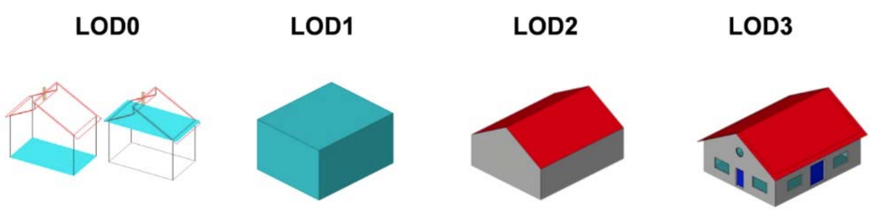

Figure 2: Representation of the same real-world building in the Levels of Detail 0-3

Commercial GIS systems (for example [i.20]) support CityGML's LODs from 0 to 4 for building models, and if one is using QGIS, there are plugins that handle these LODs too. CityJSON [i.9] takes it further, standardizing LODs by requiring all geometry objects to have a 'lod' property, clearly defining the detail level. It can be as simple as a single digit, or more advanced, using TU Delft's improved LOD system, which brings precision to a new level.

TU Delft has improved the LOD specifications and pushed the boundaries, as illustrated in Figure 3, which is copied from [i.22].

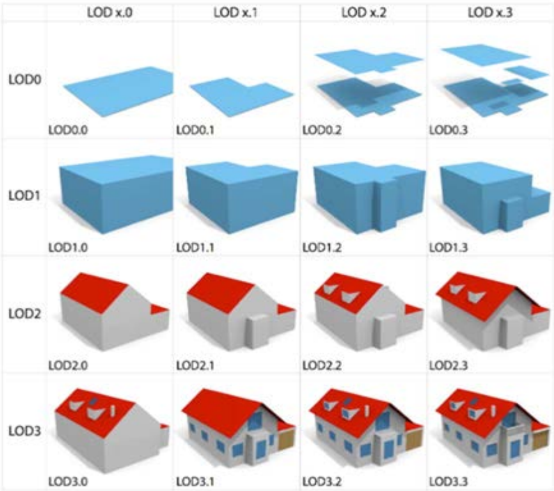

Figure 3: An improved LOD specification for 3D building models (source: [i.22])

So far, there is no evidence of cities using these advanced LODs in real-world scenarios.

6.4.2 LOIN

Level of Information Need (LOIN) is a concept used in the Building Information Modelling (BIM) field, as defined in standards like ISO 7817-1 [i.23]. It describes the level of detail and amount of information needed for a specific task or use case. LOIN is part of the ISO 19650-1 [i.24] series on BIM - Building Information Modelling, which focuses on managing information during the construction and operation of buildings using BIM.

LOIN covers three main types of information:

- **Geometry**: The level of geometric detail required.
- **Alphanumeric Information**: Non-geometric data, such as materials or costs.
- **Documentation**: Any related documents, like drawings or specifications.

The purpose of LOIN is to ensure that the right information is available at the right time for the different stakeholders involved in a project's lifecycle.

The European BIM community promotes LOIN, especially for use in collaboration during the design, construction, and delivery phases of a project. It can also be used to define the Level Of Detail (LOD) required from BIM or IFC [i.15] data, in addition to the Levels Of Detail (LOD) in CityGML.

However, there is no direct relationship between the CityGML Levels Of Detail (LOD) and LOIN. For this reason, LOIN is not used in the present document as a possible specification.

It is recommended that the LOD property in NGSI-LD should follow the CityGML standard, which defines LOD0 to LOD4, and adopt the GeoJSON approach of specifying the LOD level as a property of the geometry object.

In CityGML, the LODs are defined as specific subclasses of geometry objects, and the XML specification for the LOD levels is not explicitly used in the CityGML XSD, which is not suitable for NGSI-LD as-is (see Part 2 of CityGML [i.8], available here: https://docs.ogc.org/is/21-006r2/21-006r2.html#annex-schema).

In CityJSON the LOD has changed over the various versions of CityJSON. In the last specification it is defined as a simple mandatory enumeration in each geometry objects, while in version 1.1.3, it was defined as a string pattern, so usage of the CityJSON spec is discouraged, as it is not sufficiently stable.

6.5 3DShape

In this clause the value of a NGSI-LD Property named "3DShape", to be used for indoor locations geometries or CAD data, is specified.

There are many standards for representing shapes. From a GIS viewpoint, there are 2 main options to choose from: WKT (Well Known Text) or glTF.

WKT is an OGC standard and enables GIS databases such as PostGIS to resolve geospatial queries based on WKT data.

glTF [4] is a Khronos Group specification which is standardized in ISO with opensource libraries available. When it comes to representing complex 3D Shapes the glTF library is a de-facto standard taking advantage of the GPUs. OGC Tiles are referencing glTF as the preferred format for 3D Shapes.

Being compatible with glTF will allow NGSI-LD data to be easily shared with 3D graphics and gaming engines (Unity, Unreal Engine), Virtual reality (VR) and augmented reality (AR) applications, support asset exchanges between 3D modelling tools, and enable Web-based 3D rendering (Three.js, Babylon.js).

NOTE: glTF does not require the coordinates of the vertices to be OGC coordinates with latitude and longitude, but rather a Euclidian coordinate system with an origin and 3 axes X, Y, Z. Unfortunately, due to the historical legacy of the computer graphics industry, the Y axis is the vertical axis, and the Z axis represents the depth of a screen (which humans would more naturally consider to be the Y axis, assigning Z to vertical/elevation, instead).

There is a possible trade-off between promoting spatial queries resolution vs. ease of integration of 3D objects in smart applications.

There is value in both, so recommendation is that both should be allowed.

The recommendation is to define the value of a new 3DShape Property for indoor locations or CAD data, based on the BOT [i.25] geo-localized "hasZeroPoint" property with a CRS from which the 3D properties for indoor or CAD can be represented with relative coordinates from the "ZeroPoint" (0,0,0).

The 3DShape's value shall have the following members:

- mesh: a URI to the definition of the mesh in glTF
- wkt: a URI to the definition of the mesh in WKT
- zeroPoint: location and coordRefSys
- boundingVolume
- lod

It is needed to have one of "mesh" or "wkt".

It is needed to have one of the other members.

The following key/value pairs shall be added to the NGSI-LD core @context. For the "lod" the idea is to follow the CityGML specification (schemas are available here: https://github.com/opengeospatial/CityGML3.0-GML-Encoding/tree/main/standard/Schema), hence users should use a simple enumeration of 4 values.

```
      "3DShape": "ngsi-ld:3DShape",
      "mesh": https://registry.khronos.org/glTF/specs/2.0/glTF-2.0.html#meshes,
      "wkt": http://www.opengis.net/ont/geosparql#asWKT,
      "zeroPoint": "ngsi-ld:zeroPoint",
      "boundingVolume": https://github.com/CesiumGS/3d-tiles/blob/main/extensions/3DTILES_bounding_volume_S2/schema/boundingVolume.3DTILES_bounding_volume_S2.schema.json,
      "lod": https://raw.githubusercontent.com/opengeospatial/CityGML3.0-GML-Encoding/refs/heads/main/standard/Schema/relief.xsd
```

The following example illustrates a practical usage.

EXAMPLE: An Eiffel Tower Entity with a 3Dshape:

```
{
  "id": "urn:ngsi-ld:Building:EiffelTower",
  "type": "Building",
  "name": {
    "type": "Property",
    "value": "Eiffel Tower"
  },
  "location": {
    "type": "GeoProperty",
    "value": {
      "type": "Point",
      "coordinates": [
        2.294481,
        48.858370
      ],
      "coordRefSys": "https://www.opengis.net/def/crs/EPSG/0/7415"
    }
  },
  "3DShape": {
    "type": "Property",
    "value": {
      "mesh": "https://www.EiffelTowerManagement.com/asset/glTF/EiffelTower/LOD3",
      "wkt": "https://www.EiffelTowerManagement.com/asset/wkt/EiffelTower/LOD3",
      "zeroPoint": {
        "location": {
          "type": "Point",
          "coordinates": [
            2.294481,
            48.858370
          ],
          "coordRefSys": "https://www.opengis.net/def/crs/EPSG/0/7415"
        }
      },
      "boundingVolume": {
        "box": [
          0, 0, 10, 100, 0, 0, 0, 100, 0, 0, 0, 10
        ]
      },
      "lod": "3"
    }
  }
}
```

6.6 GeoQuery

NGSI-LD defines 7 geoqueries functions (near, within, contains, overlaps, intersects, equals and disjoint). They represent a subset of the OGC SPARQL query language which includes the following additional capabilities:

- Touches, is equivalent to near with maxDistance=0.
- Meets, is equivalent to touches.
- Crosses: could be useful to manage intersections.

- Covers, covered by: it adds a 3D or Z layering concept to the other (within, contains, overlaps, intersects, equals) queries. This can be easily added to the query language as the extra Z computation will not be expensive, especially when Z is constant in each geometry.
- Inside: it adds the third dimension to the within query. Useful for indoor locations use cases.
- Other geometric queries, which imply computations on the geometric objects: area, boundary, centroid, difference, etc. that can be complex and time consuming.

Recommendation:

It is **not** recommended that complex geometric computation be in the scope of the NGSI-LD geographical query language of a Context Broker's API, specified in clause 4.10 of ETSI GS CIM 009 [1].

Instead, it is recommended to further study the opportunity to add the {crosses, covers, coveredby, inside} set of functions to the geoquery functionality of the NGSI-LD API.

The following definitions from the GeoSPARQL standard can be used as a reference for changing clause 4.10 of the ETSI GS CIM 009 [1].

```
sfCrosses

    a rdf:Property, owl:ObjectProperty ;
    rdfs:domain :SpatialObject ;
    rdfs:range :SpatialObject ;
    rdfs:isDefinedBy
        : ,
        <http://www.opengis.net/spec/geosparql/1.0/req/topology-vocab-extension/sf-spatial-
relations> ,
        <http://www.opengis.net/spec/geosparql/1.1/req/topology-vocab-extension/sf-spatial-
relations> ;
    skos:definition """States that the subject SpatialObject spatially crosses the object
SpatialObject. DE-9IM: T*T******"""@en ;
    rdfs:seeAlso <http://dbpedia.org/resource/DE-9IM> ;
    skos:prefLabel "crosses"@en ;

ehCovers
    a rdf:Property, owl:ObjectProperty ;
    rdfs:domain :SpatialObject ;
    rdfs:range :SpatialObject ;
    owl:subPropertyOf :sfContains ;
    rdfs:isDefinedBy
        : ,
        <http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/eh-spatial-relations> ,
        <http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/eh-spatial-relations> ;
    skos:definition """States that the subject SpatialObject spatially covers the object
SpatialObject. DE-9IM: T*TFT*FF*"""@en ;
    rdfs:seeAlso <http://dbpedia.org/resource/DE-9IM> ;
    skos:prefLabel "covers"@en ;

ehCoveredBy
    a rdf:Property, owl:ObjectProperty ;
    rdfs:domain :SpatialObject ;
    rdfs:range :SpatialObject ;
    owl:subPropertyOf :sfWithin ;
    rdfs:isDefinedBy
        : ,
        <http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/eh-spatial-relations> ,
        <http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/eh-spatial-relations> ;
    skos:definition """States that the subject SpatialObject is spatially covered by the object
SpatialObject. DE-9IM: TFF*TFT**"""@en ;
    rdfs:seeAlso <http://dbpedia.org/resource/DE-9IM> ;
    skos:prefLabel "covered by"@en ;


ehInside
    a rdf:Property, owl:ObjectProperty ;
    rdfs:domain :SpatialObject ;
    rdfs:range :SpatialObject ;
    owl:subPropertyOf :sfWithin ;
    rdfs:isDefinedBy
        : ,
        <http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/eh-spatial-relations> ,
        <http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/eh-spatial-relations> ;
```

```
    skos:definition """States that the subject SpatialObject is spatially inside the object
SpatialObject. DE-9IM: TFF*FFT**"""@en ;
    rdfs:seeAlso <http://dbpedia.org/resource/DE-9IM> ;
    skos:prefLabel "inside"@en ;
```

Annex A (informative): Descriptions of Standards

The recommendations of the present document are based on the specifications contained in the following standards.

Table A.1: Coordinate Reference Systems (CRS) description

Standard name	**OGC API - Features - Part 2 : Coordinate Reference Systems by Reference [i.12]**
Full name	OGC API - Features - Part 2 : Coordinate Reference Systems by Reference [i.12]
Version	Version 1.0
Status	Released
Documentation	https://docs.ogc.org/is/18-058/18-058.html
Formats	GML [i.7] /XML, GeoJSON/JSON, HTML
Description	CRS Systems by Reference specifies an extension to the OGC API - Features - Part 1: Core standard that defines the behaviour of a server that supports the ability to present geometry valued properties in a response document in one from a list of supported Coordinates Reference Systems (CRS). It assumes that each supported CRS can be referenced by a uniform resource identifier (i.e. a URI) such as http://www.opengis.net/def/crs/EPSG/0/4326. It specifies: • How, for each offered feature collection, a server advertises the list of supported CRS identifiers; • How the coordinates of geometry valued feature properties can be accessed in one of the supported CRSs; • How features can be accessed from the server using a bounding box specified in one of the supported CRSs; and • How a server can declare the coordinate reference system used to present feature resources.
Maturity	
NGSI-LD Cross Domain usage	Include a CRS property in the GeoProperty values. See clause 6.2

Table A.2: CityJSON description

Standard name	**CityJSON [**
Full name	CityJSON Community Standard
Version	Version 2.0
Status	Released
Documentation	https://docs.ogc.org/cs/20-072r5/20-072r5.html
Data model	https://cityjson.org/schemas
Formats	JSON
Description	CityJSON is a JSON-based encoding for a well-documented subset of the OGC CityGML data model (version 3.0.0). CityJSON defines how to store digital 3D models of cities and landscapes. The aim of CityJSON is to offer an alternative to the GML encoding of CityGML, which can be verbose and complex to read and manipulate. CityJSON aims at being easy-to-use, both for reading datasets and for creating them. It was designed with programmers in mind, so that tools and APIs supporting it can be quickly built.
Maturity	
NGSI-LD Cross Domain usage	Features are identified. Locations can be identified through the fact that a Feature has a location. Use the serialization proposal in clause 6.4.1, taking into account that the CityJSON is not a very stable specification.

Table A.3: IFC description

Standard name	**IFC [ ]**
Full name	Industry Foundation Classes
Full name	Industry Foundation Classes
Version	4.0.2.1 (Version 4.0 - Addendum 2 - Technical Corrigendum 1)
Status	Republished by ISO as ISO 16739-1:2018
Documentation	https://standards.buildingsmart.org/IFC/RELEASE/IFC4/ADD2_TC1/HTML
Ontology	https://standards.buildingsmart.org/IFC/DEV/IFC4/ADD2/OWL/index.html
Formats	Express, XSD, RDF, TTL (IFcOWL)
Description	The Industry Foundation Classes, IFC, are an open international standard for Building Information Model (BIM) data that are exchanged and shared among software applications used by the various participants in the construction or facility management industry sector. The standard includes definitions that cover data required for buildings over their life cycle. Current release, and upcoming releases, extend the scope to include data definitions for infrastructure assets over their life cycle as well.
Main concepts	Spatial structures: Site, Building, Story, Space Building elements: Wall, Roof, Slab, Beam, Door, Window, etc. Equipment and systems: Electricity, HVAC, Plumbing, etc. All types of relations between the previous elements Specific properties (Psets) and quantities (Qto) for each element type.
Maturity	Widely used for building design and construction phases Starting to be used in building exploitation phase.
NGSI-LD Cross Domain usage	Inspiration for 3DShape Property for Indoor Locations or CAD data with local coordinates system with a geo-localized zero-point, a transformation matrix and a CRS. See clause 6.5

Table A.4: CityGML description

Standard name	**CityGML [i.8]**
Full name	OGC City Geography Markup Language
Version	Version 3.0
Status	Released
Documentation	https://docs.ogc.org/is/21-006r2/21-006r2.html
Data model	https://github.com/opengeospatial/CityGML-3.0CM/tree/master/Implementations
Formats	GML, JSON, SQL
Description	The CityGML standard defines a conceptual model and exchange format for the representation, storage and exchange of virtual 3D city models. It facilitates the integration of urban geodata for a variety of applications for Smart Cities and Urban Digital Twins, including urban and landscape planning; Building Information Modelling (BIM); mobile telecommunication; disaster management; 3D cadastre; tourism; vehicle & pedestrian navigation; autonomous driving and driving assistance; facility management, and; energy, traffic and environmental simulations.
Maturity	CityGML has gained significant adoption in urban planning, geospatial industries, and 3D city modelling projects worldwide. Its adoption indicates a degree of maturity and acceptance within the relevant communities.
NGSI-LD Cross domain usage	Use CityGML LOD definition. See clause 6.4.1.

Table A.5: OGC GeoSPARQL description

Standard name	**GeoSPARQL [3]**
Full name	Geographic Vocabulary and Query Language for RDF Data
Version	Approved 1.0 1.1 Draft
Status	Approved OGC Implementation Standard
Documentation	https://www.ogc.org/standards/geosparql (v1.0) https://opengeospatial.github.io/ogc-geosparql/geosparql11/document.html (v1.1)
Ontology	geo: http://www.opengis.net/#geosparql geof: http://www.opengis.net/def/function/geosparql/ w3cGeo: http://www.w3.org/2003/01/geo/wgs84_pos# geor: http://www.opengis.net/def/rule/geosparql/ sf: http://www.opengis.net/ont/sf#
Formats	RDF, GeoJSON-LD. Compatible with GeoJSON, KML, GML, WKT
Description	This ontology is related to other complementary OGC standards and ontologies : WKT, GML, WGS84.
Maturity	GeoSPARQL is a well-established standard developed by the Open Geospatial Consortium (OGC) for representing and querying geospatial information in RDF (Resource Description Framework) data stores. The standard has been widely adopted in the geospatial and semantic web communities, and it has seen implementation in various systems and applications. GeoSPARQL has been implemented in various RDF triple stores, and there are tools and libraries available that support its use.
NGSI-LD usage	Add the following functions from GeoSPARQL: crosses, covered by, inside.

Table A.6: glTF description

Standard name	**glTF™ [4]**
Full name	GL Transmission Format
Version	GlTF 2.0
Status	Released
Documentation	https://registry.khronos.org/glTF/specs/2.0/glTF-2.0.html
Description	glTF™ is a royalty-free specification for the efficient transmission and loading of 3D scenes and models by engines and applications. glTF minimizes the size of 3D assets, and the runtime processing needed to unpack and use them. glTF defines an extensible, publishing format that streamlines authoring workflows and interactive services by enabling the interoperable use of 3D content across the industry. glTF 2.0 has been released as the ISO/IEC 12113 [4]:2022 International Standard.
Main concepts	Scene, node, mesh, camera, material, texture.
Maturity	glTF is a mature, robust, and widely adopted 3D file format, well-suited for a variety of applications from web to VR/AR.
NGSI-LD usage	Representing 3DShapes in a compact format. to be used as a 3DShape attribute.

Annex B (informative): Change history

Date	Version	Information about changes
June 2024	0.0.1	First version
August 2024	0.0.2	Revision according to TB indications
October 2024	0.0.3	Final draft, Technical Officer Review for EditHelp publication preprocessing after TB approval

History

Document history		
V1.1.1	November 2024	Publication