OGC SensorThings API
Part 1: Sensing

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http://docs.opengeospatial.org/is/15-078r6/15-078r6.html

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i. Abstract
The OGC SensorThings API provides an open, geospatial-enabled and unified way to interconnect the Internet of Things (IoT) devices, data, and applications over the Web. At a high level the OGC SensorThings API provides two main functionalities and each function is handled by a part. The two parts are the Sensing part and the Tasking part. The Sensing part provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems. The Tasking part is planned as a future work activity and will be defined in a separate document as the Part II of the SensorThings API.

ii. Keywords
The following are keywords to be used by search engines and document catalogues.
ogcdoc, OGC document, iot, internet of things, sensor things, sensors, swe, sensor webs, sensor web enablement, sensor networks

iii. Preface
The OGC SensorThings API provides an open, geospatial-enabled and unified way to interconnect the Internet of Things devices, data, and applications over the Web. The OGC SensorThings API is an open standard, and that means it is non-proprietary, platform-independent, and perpetual royalty-free. Although it is a new standard, it builds on a rich set of proven-working and widely-adopted open standards, such as the Web protocols and the OGC Sensor Web Enablement (SWE) standards, including the ISO/OGC Observation and Measurement data model [OGC 10-004r3 and ISO 19156:2011]. That also means the OGC SensorThings API is extensible and can be applied to not only simple but also complex use cases.

At a high level the OGC SensorThings API provides two main functionalities and each function is handled by a part. The two parts are the Part I - Sensing and the Part II - Tasking. The Sensing part provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems. The Tasking part provides a standard way for parameterizing - also called tasking - of task-able IoT devices, such as sensors or actuators. The Tasking part is planned as a future work activity and will be defined in a separate document as the Part II of the SensorThings API.

The Sensing part provides functions similar to the OGC Sensor Observation Service (SOS) and the Tasking part will provide functions similar to the OGC Sensor Planning Service (SPS). The main difference between the SensorThings API and the OGC SOS and SPS is that the SensorThings API is designed specifically for the resource-constrained IoT devices and the Web developer community. As a result, the SensorThings API follows the REST principles, the use of an efficient JSON encoding, the use of MQTT protocol, the use of the flexible OASIS OData protocol and URL conventions.
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iv. Submitting organizations

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- National Central University, Taiwan
- Lockheed Martin, USA
- AIST, Japan
- FCU.GIS, Taiwan
- ITRI, Taiwan
- GeoConnections, Canada
- Noblis, USA
- Fraunhofer, Germany

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<td>NRCan/Canadian Geospatial Data Infrastructure</td>
</tr>
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</table>
1. Scope

The OGC SensorThings API provides an open standard-based and geospatial-enabled framework to interconnect the Internet of Things devices, data, and applications over the Web.

2. Conformance

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site.1

All requirements-classes and conformance-classes described in this document are owned by the standard(s) identified.

The following table list the requirements classes defined by this standard.

NOTE: The smaller blue text in the following table is the path fragment that appended to the following URI: http://www.opengis.net/spec/iot_sensing/1.0/, and it provides the URI that can be used to unambiguously identify the requirement and the conformance class.

<table>
<thead>
<tr>
<th>Requirements class id</th>
<th>Requirements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>req/thing</td>
<td>• req/thing/properties • req/thing/relations</td>
<td>Thing entity</td>
</tr>
<tr>
<td>req/location</td>
<td>• req/location/properties • req/location/relations</td>
<td>Location entity</td>
</tr>
<tr>
<td>req/historical-location</td>
<td>• req/historical-location/properties • req/historical-location/relations</td>
<td>HistoricalLocation entity</td>
</tr>
<tr>
<td>req/datastream</td>
<td>• req/datastream/properties • req/datastream/relations</td>
<td>Datastream entity</td>
</tr>
<tr>
<td>req/sensor</td>
<td>• req/sensor/properties • req/sensor/relations</td>
<td>Sensor Entity</td>
</tr>
</tbody>
</table>

1 www.opengeospatial.org/cite
<table>
<thead>
<tr>
<th>req/observed-property</th>
<th>• req/observed-property/properties • req/observed-property/relations</th>
<th>ObservedProperty entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>req/observation</td>
<td>• req/observation/properties • req/observation/relations</td>
<td>Observation entity</td>
</tr>
<tr>
<td>req/feature-of-interest</td>
<td>• req/feature-of-interest/properties • req/feature-of-interest/relations</td>
<td>FeatureOfInterest entity</td>
</tr>
<tr>
<td>req/entity-control-information</td>
<td>• req/entity-control-information/common-control-information</td>
<td>Entities’ common control information</td>
</tr>
<tr>
<td>req/resource-path</td>
<td>• req/resource-path/resource-path-to-entities</td>
<td>Addressing to the entities of the SensorThings API service</td>
</tr>
<tr>
<td>req/request-data</td>
<td>• req/request-data/order • req/request-data/expand • req/request-data/select • req/request-data/status-code • req/request-data/query-status-code • req/request-data/orderby • req/request-data/top • req/request-data/skip • req/request-data/count • req/request-data/filter • req/request-data/built-in-filter-operations • req/request-data/built-in-filter-functions • req/request-data/pagination</td>
<td>Requesting data with system query options</td>
</tr>
<tr>
<td>req/create-update-delete</td>
<td>• req/create-update-delete/create-entity • req/create-update-delete/link-to-existing-entities • req/create-update-delete/deep-insert • req/create-update-delete/deep-insert-status-code • req/create-update-delete/update-entity • req/create-update-delete/delete-entity • req/create-update-delete/historical-location-auto-creation</td>
<td>Creating, updating, and deleting entities</td>
</tr>
<tr>
<td>req/batch-request</td>
<td>• req/batch-request/batch-request</td>
<td>Processing multiple requests with a single request</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>req/multi-datasream</td>
<td>• req/multi-datasream/properties • req/multi-datasream/relations • req/multi-datasream/constraints</td>
<td>Handling complex observations with complex results, especially when the result is an array.</td>
</tr>
<tr>
<td>req/data-array</td>
<td>• req/data-array/data-array</td>
<td>Serving Observations with the efficient data array encoding</td>
</tr>
<tr>
<td>req/create-observations-via-mqtt</td>
<td>• req/create-observations-via-mqtt/observations-creation</td>
<td>creating observations through MQTT</td>
</tr>
<tr>
<td>req/receive-updates-via-mqtt</td>
<td>• req/receive-updates-via-mqtt/receive-updates</td>
<td>Receiving updates through MQTT</td>
</tr>
</tbody>
</table>

### 3. References

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

<table>
<thead>
<tr>
<th>ISO 8601:2004 Data elements and interchange formats – Information interchange - Representation of dates and times.</th>
</tr>
</thead>
<tbody>
<tr>
<td>OASIS OData Version 4.0 Part 1: Protocol Plus Errata 02</td>
</tr>
<tr>
<td>OASIS OData Version 4.0 Part 2: URL Conventions Plus Errata 02</td>
</tr>
</tbody>
</table>
4. Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

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

4.1 Collection
Sets of Resources, which can be retrieved in whole or in part. [RFC5023]

4.2 Entity
Entities are instances of entity types. [OASIS OData Version 4.0 Part 1: Protocol Plus Errata 02]

*Note: Thing, Sensor, Datastream, Observation are some example entity types of the OGC SensorThings API.*

4.3 Entity sets
Entity sets are named collections of entities (e.g. Sensors is an entity set containing Sensor entities). An entity's key uniquely identifies the entity within an entity set. Entity sets provide entry points into an OGC SensorThings API service. [OASIS OData Version 4.0 Part 1: Protocol Plus Errata 02]
4.4 (Internet of) Thing
A thing is an object of the physical world (physical things) or the information world (virtual things) that is capable of being identified and integrated into communication networks. [ITU-T Y.2060]

4.5 Measurement
A set of operations having the object of determining the value of a quantity [OGC 10-004r3 / ISO 19156:2011]

4.6 Observation
Act of measuring or otherwise determining the value of a property [OGC 10-004r3 / ISO 19156:2011]

4.7 Observation Result
Estimate of the value of a property determined through a known observation procedure [OGC 10-004r3 / ISO 19156:2011]

4.8 Resource
A network-accessible data object or service identified by an URI, as defined in [RFC 2616]

4.9 REST
The Representational State Transfer (REST) style is an abstraction of the architectural elements within a distributed hypermedia system. REST focuses on the roles of components, the constraints upon their interaction with other components, and their interpretation of significant data elements. It encompasses the fundamental constraints upon components, connectors, and data that define the basis of the Web architecture, and thus the essence of its behavior as a network-based application. An API that conforms to the REST architectural principles/constraints is called a RESTful API.

4.10 Sensor
An entity capable of observing a phenomenon and returning an observed value. Type of observation procedure that provides the estimated value of an observed property at its output. [OGC 12-000]
5. Conventions

This section provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

5.1 Presentation of Requirements and Recommendations
Requirements are presented using the following style:

```
Req <number> <requirement text>
<requirement id>
```

<number> is a unique number within the document.

<br> is the requirement itself. Normative verbs like SHALL are written in capitals.

The smaller blue text at the bottom of the box <requirement id> is the path and it provides the URI of the requirement which can be used to unambiguously identify the requirement.

Normative verbs like SHALL are written in capitals.

5.2 Identifiers
The normative provisions in this specification are denoted by the URI

http://www.opengis.net/spec/iot_sensing/1.0/

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

6. Symbols (and abbreviated terms)

<table>
<thead>
<tr>
<th>API</th>
<th>Application Programming Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-W</td>
<td>Catalog Service Web</td>
</tr>
<tr>
<td>CRUD</td>
<td>Create, Read, Update, and Delete</td>
</tr>
<tr>
<td>GML</td>
<td>Geography Markup Language</td>
</tr>
<tr>
<td>HTML</td>
<td>HyperText Markup Language</td>
</tr>
<tr>
<td>HTTP</td>
<td>Hypertext Transfer Protocol</td>
</tr>
</tbody>
</table>
7. SensorThings API overview

7.1 Who should use the OGC SensorThings API
Organizations that need web-based platforms to manage, store, share, analyze IoT-based sensor observation data should use the OGC SensorThings API. The OGC SensorThings API simplifies and accelerates the development of IoT applications. Application developers can use this open standard to connect to various IoT devices and create innovative applications without worrying the daunting heterogeneous protocols of the different IoT devices, gateways, and services. IoT device manufacturers can also use OGC SensorThings API as the API can be embedded within various IoT hardware and software platforms, so that the various IoT devices can effortlessly connect with the OGC standard-compliant servers around the world. In summary, the OGC SensorThings API is transforming the numerous disjointed IoT systems into a fully connected platform where complex tasks can be synchronized and performed.

7.2 Benefits of the OGC SensorThings API
In today’s world, most IoT devices (e.g., sensors and actuators) have proprietary software interfaces defined by their manufacturers and used selectively. New APIs are often
required and developed on an as-needed basis, often in an environment with resource limitations and associated risks. This situation requires significant investment on the part of developers for each new sensor or project involving multiple systems and on the part of the providers of sensors, gateways and portals or services where observations and measurements are required.

As a standardized data model and interface for sensors in the WoT and IoT, the OGC SensorThings API offers the following benefits: (1) it permits the proliferation of new high value services with lower overhead of development and wider reach, (2) it lowers the risks, time and cost across a full IoT product cycle, and (3) it simplifies the connections between devices-to-devices and devices-to-applications.

7.3 SensorThings API Overview

The OGC SensorThings API data model consists of two parts: (1) the Sensing part and (2) the Tasking part. The Sensing part allows IoT devices and applications to CREATE, READ, UPDATE, and DELETE (i.e., HTTP POST, GET, PATCH, and DELETE) IoT data and metadata in a SensorThings service.

The Sensing part is designed based on the ISO/OGC Observation and Measurement (O&M) model [OGC 10-004r3 and ISO 19156:2011]. The key to the model is that an Observation is modeled as an act that produces a result whose value is an estimate of a property of the observation target or FeatureOfInterest. An Observation instance is classified by its event time (e.g., resultTime and phenomenonTime), FeatureOfInterest, ObservedProperty, and the procedure used (often a Sensor). Moreover, Things are also modeled in the SensorThings API, and its definition follows the ITU-T definition: “an object of the physical world (physical things) or the information world (virtual things) that is capable of being identified and integrated into communication networks” [ITU-T Y.2060].

The geographical Locations of Things are useful in almost every application and as a result are included as well. For the Things whose location changed, the HistoricalLocations entities offer the history of the Thing’s locations. A Thing also can have multiple Datastreams. A Datastream is a collection of Observations grouped by the same ObservedProperty and Sensor. An Observation is an event performed by a Sensor that produces a result whose value is an estimate of an ObservedProperty of the FeatureOfInterest. Details of each above described entity are provided in Section 8.

7.4 SensorThings API and ISO/OGC Observations and Measurements

Managing and retrieving observations and metadata from IoT sensor systems is one of the most common use cases. As a result, SensorThings API’s sensing part is designed based on the ISO/OGC Observation and Measurement (O&M) model [OGC 10-004r3 and ISO 19156:2011]. O&M defines models for the exchange of information describing observation acts, their results as well as the feature involved in sampling when making observations.

---

2 The two terms of IoT and WoT are frequently used interchangeably.
SensorThings API defines eight entities for the IoT sensing applications. Table 1 lists each component and its relationship with O&M. Low-cost and simple sensors are key enablers for the vision of IoT. As a result, SensorThings API uses the term of sensor to describe the procedure that is used in making an observation, instead of using O&M’s term of procedure.

Table 1 SensorThings API Sensing entities and equivalent concepts in O&M 2.0

<table>
<thead>
<tr>
<th>SensorThings API Entities</th>
<th>O&amp;M 2.0 Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thing (and Locations, HistoricalLocations)</td>
<td>-</td>
</tr>
<tr>
<td>Datastream</td>
<td>-</td>
</tr>
<tr>
<td>Sensor</td>
<td>Procedure</td>
</tr>
<tr>
<td>Observation</td>
<td>Observation</td>
</tr>
<tr>
<td>ObservedProperty</td>
<td>Observed Property</td>
</tr>
<tr>
<td>FeatureOfInterest</td>
<td>Feature-Of-Interest</td>
</tr>
</tbody>
</table>

7.5 SensorThings API and OASIS OData

SensorThings API follows OData’s specification for requesting entities. That means the entity control information, resource path usages, query options, the relevant JSON encodings, and batch-processing request follow OData 4.0. By using OData’s standard ways for requesting entities, developers who are familiar with OData can create SensorThings applications easily. However, SensorThings API does not follow the OData Common Schema Definition Language and as a result does not follow its metadata service entity model. Thus, SensorThings API should not be seen as an OData compliant API. SensorThings API’s future work will explore possible harmonization between SensorThings API and OData.

7.6 SensorThings API and OGC Key-Value Pair (KVP) Encodings

Please note that SensorThings API’s Key-Value Pair (KVP) encoding is different from many existing OGC service implementation standards, such as SOS or Web Map Service (WMS). The main reason is that OData offers a complete set of KVP encodings (see Clause 9.3.3.6) that is designed specifically for RESTful web services, while OGC baseline currently does not have common KVP encodings for the RESTful binding. As a result, OGC SensorThings API version 1.0 chooses to use OData KVP encodings only. It is our future work to support OGC KVP encodings as an extension once a common OGC RESTful binding is available.

7.7 SensorThings API and Security

As things in the Internet of Things are connected to the network. Such ubiquitous network connectivity results in significant security threats. In the IoT reference model defined by ITU-T [ITU-T Y.2060] IoT security capabilities are not an independent layer but must be associated with all layers. The following figure show the ITU-T IoT...
reference model. The reference model has four layers, namely (1) Applications Layer, (2) Service Support and Application Support Layer, (3) Network Layer, and (4) Device Layer. And security capabilities are a cross-layer component that is associated with the four layers.

Based on the IoT reference model, SensorThings API falls into the scope of the Service Support and Application Support Layer and the security issues should be addressed by the cross-cutting security capabilities. As a result, SensorThings API does not define specific security capabilities. Instead SensorThings API is designed to leverage the existing and future IoT security capabilities.

![IoT Reference Model](https://via.placeholder.com/150)

Figure 1 IoT Reference Model (adapted from [ITU-T Y.2060])

8. The SensorThings API Sensing Entities

8.1 Common Control Information

<table>
<thead>
<tr>
<th>Requirements Class</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Type</td>
<td>Web Service</td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a></td>
</tr>
</tbody>
</table>

Req 1 Each entity SHALL have the following common control information listed in Table 2.

http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information
In SensorThings control information is represented as annotations whose names start with `iot` followed by a dot (.). Annotations are name/value pairs that have a dot (.) as part of the name.

When annotating a name/value pair for which the value is represented as a JSON object, each annotation is placed within the object and represented as a single name/value pair. In SensorThings the name always starts with the "at" sign (@), followed by the namespace `iot`, followed by a dot (.), followed by the name of the term (e.g., `@iot.id":1`).

When annotating a name/value pair for which the value is represented as a JSON array or primitive value, each annotation that applies to this name/value pair is placed next to the annotated name/value pair and represented as a single name/value pair. The name is the same as the name of the name/value pair being annotated, followed by the “at” sign (@), followed by the namespace `iot`, followed by a dot (.), followed by the name of the term. (e.g., "Locations@iot.navigationLink":"http://example.org/v.1.0/Things(1)/Locations")

<table>
<thead>
<tr>
<th>Annotation</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>id</code></td>
<td><code>id</code> is the system-generated identifier of an entity. <code>id</code> is unique among the entities of the same entity type in a SensorThings service.</td>
<td>Any</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><code>selfLink</code></td>
<td><code>selfLink</code> is the absolute URL of an entity that is unique among all other entities.</td>
<td>URL</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><code>navigationLink</code></td>
<td><code>navigationLink</code> is the relative or absolute URL that retrieves content of related entities.</td>
<td>URL</td>
<td>One-to-many (mandatory)</td>
</tr>
</tbody>
</table>

8.2 The Sensing Entities
The SensorThings API Sensing part’s Entities are depicted in Figure 2.
In this section, we explain the properties in each entity type and the direct relation to the other entity types. In addition, for each entity type, we show an example of the associated JSON encoding.

### 8.2.1 Thing

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/thing">http://www.opengis.net/spec/iot_sensing/1.0/req/thing</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Service</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/thing/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/thing/properties</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/thing/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/thing/relations</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a></td>
</tr>
</tbody>
</table>
The OGC SensorThings API follows the ITU-T definition, i.e., with regard to the Internet of Things, a thing is an object of the physical world (physical things) or the information world (virtual things) that is capable of being identified and integrated into communication networks [ITU-T Y.2060].

Req 2 Each Thing entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 3.

http://www.opengis.net/spec/iot_sensing/1.0/req/thing/properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>A property provides a label for Thing entity, commonly a descriptive name.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>description</td>
<td>This is a short description of the corresponding Thing entity.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>properties</td>
<td>A JSON Object containing user-annotated properties as key-value pairs.</td>
<td>JSON Object</td>
<td>Zero-to-one</td>
</tr>
</tbody>
</table>

Req 3 Each Thing entity SHALL have the direct relation between a Thing entity and other entity types listed in Table 4.

http://www.opengis.net/spec/iot_sensing/1.0/req/thing/relations

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Many optional to many optional</td>
<td>The Location entity locates the Thing. Multiple Things MAY be located at the same Location. A Thing MAY not have a Location. A Thing SHOULD have only one Location. However, in some complex use cases, a Thing MAY have more than one Location representations. In such case, the Thing MAY have more than one Locations. These Locations SHALL have different encodingTypes and the encodingTypes SHOULD be in different spaces (e.g., one encodingType in Geometrical space and one encodingType in Topological space).</td>
</tr>
<tr>
<td>HistoricalLocation</td>
<td>One mandatory to many optional</td>
<td>A Thing has zero-to-many HistoricalLocations. A HistoricalLocation has one-and-only-one Thing.</td>
</tr>
<tr>
<td>Datastream</td>
<td>One mandatory to many optional</td>
<td>A Thing MAY have zero-to-many Datastreams.</td>
</tr>
</tbody>
</table>
Example 1 an example of a Thing entity:

```
{
  "@iot.id": 1,
  "@iot.selfLink": "http://example.org/v1.0/Things(1)",
  "Locations@iot.navigationLink": "Things(1)/Locations",
  "Datastreams@iot.navigationLink": "Things(1)/Datastreams",
  "HistoricalLocations@iot.navigationLink": "Things(1)/HistoricalLocations",
  "name": "Oven",
  "description": "This thing is an oven.",
  "properties": {
    "owner": "Noah Liang",
    "color": "Black"
  }
}
```

8.2.2 Location

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/location">http://www.opengis.net/spec/iot_sensing/1.0/req/location</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/location/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/location/properties</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/location/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/location/relations</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a></td>
</tr>
</tbody>
</table>

The Location entity locates the Thing or the Things it associated with. A Thing’s Location entity is defined as the last known location of the Thing.

A Thing’s Location may be identical to the Thing’s Observations’ FeatureOfInterest. In the context of the IoT, the principle location of interest is usually associated with the location of the Thing, especially for in-situ sensing applications. For example, the location of interest of a wifi-connected thermostat should be the building or the room in which the smart thermostat is located. And the FeatureOfInterest of the Observations made by the thermostat (e.g., room temperature readings) should also be the building or the room. In this case, the content of the smart thermostat’s location should be the same as the content of the temperature readings’ feature of interest.

However, the ultimate location of interest of a Thing is not always the location of the Thing (e.g., in the case of remote sensing). In those use cases, the content of a Thing’s
Location is different from the content of the FeatureOfInterest of the Thing’s Observations. Section 7.1.4 of [OGC 10-004r3 and ISO 19156:2011] provides a detailed explanation of observation location.

### Req 4
Each Location entity SHALL have the mandatory properties listed in Table 5.

http://www.opengis.net/spec/iot_sensing/1.0/req/location/properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>A property provides a label for Location entity, commonly a descriptive name.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>description</td>
<td>The description about the Location.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>encodingType</td>
<td>The encoding type of the Location property. Its value is one of the ValueCode enumeration (see Table 7).</td>
<td>ValueCode</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>location</td>
<td>The location type is defined by encodingType.</td>
<td>Any (i.e., the type is depending on the value of the encodingType)</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

### Req 5
Each Location entity SHALL have the direct relation between a Location entity and other entity types listed in Table 6.

http://www.opengis.net/spec/iot_sensing/1.0/req/location/relations

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thing</td>
<td>Many optional to many optional</td>
<td>Multiple Things MAY locate at the same Location. A Thing MAY not have a Location.</td>
</tr>
<tr>
<td>HistoricalLocation</td>
<td>Many mandatory to many optional</td>
<td>A Location can have zero-to-many HistoricalLocations. One HistoricalLocation SHALL have one or many Locations.</td>
</tr>
</tbody>
</table>


Example 2 an example of a Location entity:

```json
{
    "@iot.id": 1,
    "@iot.selfLink": "http://example.org/v1.0/Locations(1)",
    "Things@iot.navigationLink": "Locations(1)/Things",
    "HistoricalLocations@iot.navigationLink": "Locations(1)/HistoricalLocations",
    "encodingType": "application/vnd.geo+json",
    "name": "CCIT",
    "description": "Calgary Center for Innovative Technologies",
    "location": {
        "type": "Feature",
        "geometry": {
            "type": "Point",
            "coordinates": [-114.06, 51.05]
        }
    }
}
```

Table 7 List of some code values used for identifying types for the encodingType of the Location and FeatureOfInterest entity

<table>
<thead>
<tr>
<th>Location encodingType</th>
<th>ValueCode Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GeoJSON</td>
<td>application/vnd.geo+json</td>
</tr>
</tbody>
</table>

A thing can be geo-referenced in different spaces. For example, for some applications it is more suitable to use a topological space model (e.g., IndoorGML) to describe an indoor things’ location rather than using a geometric space model (e.g., GeoJSON). Currently GeoJSON is the only Location encodingType of the SensorThings API. In the future we expect to extend SensorThings API’s capabilities by adding additional encodingType to the code values listed in the above table. For example, one potential new Location encodingType can be a JSON encoding for IndoorGML.

8.2.3 HistoricalLocation

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location">http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/properties</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/relations</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-auto-creation">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-auto-creation</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-</a></td>
</tr>
</tbody>
</table>
A Thing’s HistoricalLocation entity set provides the times of the current (*i.e.*, last known) and previous locations of the Thing.

<table>
<thead>
<tr>
<th>Req 6</th>
<th>Each HistoricalLocation entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 8.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/properties</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Req 7</th>
<th>Each HistoricalLocation entity SHALL have the direct relation between a Location entity and other entity types listed in Table 9.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/relations</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Req 8</th>
<th>When a Thing has a new Location, a new HistoricalLocation SHALL be created and added to the Thing automatically by the service. The current Location of the Thing SHALL only be added to HistoricalLocation automatically by the service, and SHALL not be created as HistoricalLocation directly by user.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-auto-creation">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-auto-creation</a></td>
</tr>
</tbody>
</table>

The HistoricalLocation can also be created, updated and deleted. One use case is to migrate historical observation data from an existing observation data management system to a SensorThings API system.

**Table 8 Properties of a HistoricalLocation entity**

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>The time when the Thing is known at the Location.</td>
<td>TM_Instant (ISO-8601 Time String)</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

**Table 9 Direct relation between an HistoricalLocation entity and other entity types**

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Many optional to many mandatory</td>
<td>A Location can have zero-to-many HistoricalLocations. One HistoricalLocation SHALL have one or many Locations.</td>
</tr>
<tr>
<td>Thing</td>
<td>Many optional to one mandatory</td>
<td>A HistoricalLocation has one-and-only-one Thing. One Thing MAY have zero-to-many HistoricalLocations.</td>
</tr>
</tbody>
</table>
Example 3 An example of a HistoricalLocations entity set (e.g., Things(1)/HistoricalLocations):

```json
{
    "value": [
        {
            "@iot.id": 1,
            "@iot.selfLink": "http://example.org/v1.0/HistoricalLocations(1)",
            "Locations@iot.navigationLink": "HistoricalLocations(1)/Locations",
            "Thing@iot.navigationLink": "HistoricalLocations(1)/Thing",
            "time": "2015-01-25T12:00:00-07:00"
        },
        {
            "@iot.id": 2,
            "@iot.selfLink": "http://example.org/v1.0/HistoricalLocations(2)",
            "Locations@iot.navigationLink": "HistoricalLocations(2)/Locations",
            "Thing@iot.navigationLink": "HistoricalLocations(2)/Thing",
            "time": "2015-01-25T13:00:00-07:00"
        }
    ],
    "@iot.nextLink": "http://example.org/v1.0/Things(1)/HistoricalLocations?$skip=2&$top=2"
}
```

8.2.4 Datastream

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/datastream">http://www.opengis.net/spec/iot_sensing/1.0/req/datastream</a></strong></td>
</tr>
<tr>
<td><strong>Target Type</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
</tr>
</tbody>
</table>

A Datastream groups a collection of Observations measuring the same ObservedProperty and produced by the same Sensor.

**Req 9** Each Datastream entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 10.

http://www.opengis.net/spec/iot_sensing/1.0/req/datastream/properties
Req 10 Each Datastream entity SHALL have the direct relation between a Datastream entity and other entity types listed in Table 11.

http://www.opengis.net/spec/iot_sensing/1.0/req/datastream/relations

<table>
<thead>
<tr>
<th>Table 10 Properties of a Datastream entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>name</td>
</tr>
<tr>
<td>description</td>
</tr>
<tr>
<td>unitOfMeasurement</td>
</tr>
<tr>
<td>Note: When a Datastream does not have a unit of measurement (e.g., a OM_TruthObservation type), the corresponding unitOfMeasurement properties SHALL have null values.</td>
</tr>
<tr>
<td>observationType</td>
</tr>
<tr>
<td>observedArea</td>
</tr>
<tr>
<td>phenomenonTime</td>
</tr>
<tr>
<td>resultTime</td>
</tr>
</tbody>
</table>

<p>| Table 11 Direct relation between a Datastream entity and other entity types |</p>
<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thing</td>
<td>Many optional to one mandatory</td>
<td>A Thing has zero-to-many Datastreams. A Datastream entity SHALL only link to a Thing as a collection of Observations.</td>
</tr>
</tbody>
</table>
Sensor | Many optional to one mandatory | The Observations in a Datastream are performed by one-and-only-one Sensor. One Sensor MAY produce zero-to-many Observations in different Datastreams.
---|---|---
ObservedProperty | Many optional to one mandatory | The Observations of a Datastream SHALL observe the same ObservedProperty. The Observations of different Datastreams MAY observe the same ObservedProperty.
Observation | One mandatory to many optional | A Datastream has zero-to-many Observations. One Observation SHALL occur in one-and-only-one Datastream.

Example 4 A Datastream entity example:

```json
{
    "@iot.id": 1,
    "@iot.selfLink": "http://example.org/v1.0/Datastreams(1)",
    "Thing@iot.navigationLink": "HistoricalLocations(1)/Thing",
    "Sensor@iot.navigationLink": "Datastreams(1)/Sensor",
    "ObservedProperty@iot.navigationLink": "Datastreams(1)/ObservedProperty",
    "Observations@iot.navigationLink": "Datastreams(1)/Observations",
    "name": "oven temperature",
    "description": "This is a datastream measuring the air temperature in an oven.",
    "unitOfMeasurement": {
        "name": "degree Celsius",
        "symbol": "°C",
        "definition": "http://unitsofmeasure.org/ucum.html#para-30"
    },
    "observationType": "http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement",
    "observedArea": {"type": "Polygon", "coordinates": [[[100,0],[101,0],[101,1],[100,1],[100,0]]]}
    "phenomenonTime": "2014-03-01T13:00:00Z/2015-05-11T15:30:00Z",
    "resultTime": "2014-03-01T13:00:00Z/2015-05-11T15:30:00Z"
}
```

The `observationType` defines the result types for specialized observations [OGC 10-004r3 and ISO 19156:2011 Table 3]. The following table shows some of the `valueCodes` that maps the UML classes in O&M v2.0 [OGC 10-004r3 and ISO 19156:2011] to `observationType` names and observation result types.

<table>
<thead>
<tr>
<th>O&amp;M 2.0</th>
<th>Value Code Value (observationType names)</th>
<th>Content of result</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM_CategoryObservation</td>
<td><a href="http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_CategoryObservation">http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_CategoryObservation</a></td>
<td>URI</td>
</tr>
<tr>
<td>OM_CountObservation</td>
<td><a href="http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_CountObservation">http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_CountObservation</a></td>
<td>integer</td>
</tr>
<tr>
<td>OM_Measurement</td>
<td><a href="http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement">http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement</a></td>
<td>double</td>
</tr>
</tbody>
</table>
8.2.5 Sensor

**Requirements Class**

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/properties</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/relations</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a></td>
</tr>
</tbody>
</table>

A Sensor is an instrument that observes a property or phenomenon with the goal of producing an estimate of the value of the property.\(^3\)

**Req 11** Each Sensor entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 13.

http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/properties

**Req 12** Each Sensor entity SHALL have the direct relation between a Sensor entity and other entity types listed in Table 14.

http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/relations

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
</table>

\(^3\) In some cases, the Sensor in this data model can also be seen as the Procedure (method, algorithm, or instrument) defined in [OGC 10-004r3 and ISO 19156:2011].
A property provides a label for Sensor entity, commonly a descriptive name.

The description of the Sensor entity.

The encoding type of the metadata property. Its value is one of the ValueCode enumeration (see Table 15 for the available ValueCode).

The detailed description of the Sensor or system. The metadata type is defined by encodingType.

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datastream</td>
<td>One mandatory to many optional</td>
<td>The Observations of a Datastream are measured with the same Sensor. One Sensor MAY produce zero-to-many Observations in different Datastreams.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensor encodingType</th>
<th>ValueCode Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDF</td>
<td>application/pdf</td>
</tr>
<tr>
<td>SensorML</td>
<td><a href="http://www.opengis.net/doc/IS/SensorML/2.0">http://www.opengis.net/doc/IS/SensorML/2.0</a></td>
</tr>
</tbody>
</table>

The Sensor encodingType allows clients to know how to interpret metadata’s value. Currently SensorThings API defines two common Sensor metadata encodingTypes. Most sensor manufacturers provide their sensor datasheets in a PDF format. As a result, PDF is a Sensor encodingType supported by SensorThings API. The second Sensor encodingType is SensorML.

**Example 5 An example of a Sensor entity:**

```json
{
    "@iot.id": 1,
    "@iot.selfLink": "http://example.org/v1.0/Sensors(1)",
    "Datastreams"@iot.navigationLink": "Sensors(1)/Datastreams",
    "name": "TMP36",
    "description": "TMP36 - Analog Temperature sensor",
    "encodingType": "application/pdf",
    "metadata": "http://example.org/TMP35_36_37.pdf"
}
```

8.2.6 ObservedProperty
An ObservedProperty specifies the phenomenon of an Observation.

Req 13 Each ObservedProperty entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 16.

http://www.opengis.net/spec/iot_sensing/1.0/req/observed-property/properties

Req 14 Each ObservedProperty entity SHALL have the direct relation between a ObservedProperty entity and other entity types listed in Table 17.

http://www.opengis.net/spec/iot_sensing/1.0/req/observed-property/relations

### Table 16 Properties of an ObservedProperty entity

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>A property provides a label for ObservedProperty entity, commonly a descriptive name.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>definition</td>
<td>The URI of the ObservedProperty. Dereferencing this URI SHOULD result in a representation of the definition of the ObservedProperty.</td>
<td>URI</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>description</td>
<td>A description about the ObservedProperty.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

### Table 17 Direct relation between an ObservedProperty entity and other entity types

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datastream</td>
<td>One mandatory to many</td>
<td>The Observations of a Datastream observe the same ObservedProperty. The Observations of different Datastreams MAY observe the same ObservedProperty.</td>
</tr>
</tbody>
</table>
Example 6 an example ObservedProperty entity:

```json
{
  "@iot.id": 1,
  "@iot.selfLink": "http://example.org/v1.0/ObservedProperties(1)",
  "Datastreams@iot.navigationLink": "ObservedProperties(1)/Datastreams",
  "description": "The dewpoint temperature is the temperature to which the air must be cooled, at constant pressure, for dew to form. As the grass and other objects near the ground cool to the dewpoint, some of the water vapor in the atmosphere condenses into liquid water on the objects.",
  "name": "DewPoint Temperature",
  "definition": "http://dbpedia.org/page/Dew_point"
}
```

8.2.7 Observation

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req(observation)">http://www.opengis.net/spec/iot_sensing/1.0/req(observation)</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req(observation)/properties">http://www.opengis.net/spec/iot_sensing/1.0/req(observation)/properties</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req(observation)/relations">http://www.opengis.net/spec/iot_sensing/1.0/req(observation)/relations</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req(entity-control-information/common-control-information)">http://www.opengis.net/spec/iot_sensing/1.0/req(entity-control-information/common-control-information)</a></td>
</tr>
<tr>
<td>Dependency</td>
<td>urn:iso:dis:iso:19156:clause:7.2.2</td>
</tr>
</tbody>
</table>

An observation is the act of measuring or otherwise determining the value of a property [OGC 10-004r3 and ISO 19156:2011]

| Req 15 Each Observation entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 18. |
| http://www.opengis.net/spec/iot_sensing/1.0/req(observation)/properties |
Req 16 Each Observation entity SHALL have the direct relation between an Observation entity and other entity types listed in Table 19.

http://www.opengis.net/spec/iot_sensing/1.0/req/observation/relations

Table 18 Properties of an Observation entity

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenomenonTime</td>
<td>The time instant or period of when the Observation happens. Note: Many resource-constrained sensing devices do not have a clock. As a result, a client may omit phenomenonTime when POST new Observations, even though phenomenonTime is a mandatory property. When a SensorThings service receives a POST Observations without phenomenonTime, the service SHALL assign the current server time to the value of the phenomenonTime.</td>
<td>TM_Object (ISO 8601 Time string or Time Interval string (e.g., 2010-12-23T10:00:00-07:00 or 2010-12-23T10:00:00-07:00/2010-12-23T12:00:00-07:00))</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>result</td>
<td>The estimated value of an ObservedProperty from the Observation.</td>
<td>Any (depends on the observationType defined in the associated Datastream)</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>resultTime</td>
<td>The time of the Observation's result was generated. Note: Many resource-constrained sensing devices do not have a clock. As a result, a client may omit resultTime when POST new Observations, even though resultTime is a mandatory property. When a SensorThings service receives a POST Observations without resultTime, the service SHALL assign a null value to the resultTime.</td>
<td>TM_Instant (ISO 8601 Time string)</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>resultQuality</td>
<td>Describes the quality of the result.</td>
<td>DQ_Element</td>
<td>Zero-to-many</td>
</tr>
<tr>
<td>validTime</td>
<td>The time period during which the result may be used.</td>
<td>TM_Period (ISO 8601 Time Interval string)</td>
<td>Zero-to-one</td>
</tr>
<tr>
<td>parameters</td>
<td>Key-value pairs showing the environmental conditions during measurement.</td>
<td>NamedValues in a JSON Array</td>
<td>Zero-to-one</td>
</tr>
</tbody>
</table>

Table 19 Direct relation between an Observation entity and other entity types

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Datastream</strong></td>
<td>Many optional to one mandatory</td>
<td>A Datastream can have zero-to-many Observations. One Observation SHALL occur in one-and-only-one Datastream.</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>FeatureOfInterest</strong></td>
<td>Many optional to one mandatory</td>
<td>An Observation observes on one-and-only-one FeatureOfInterest. One FeatureOfInterest could be observed by zero-to-many Observations.</td>
</tr>
</tbody>
</table>

**Example 7  An Observation entity example -** The following example shows an Observation whose Datastream has an ObservationType of OM_Measurement. A result’s data type is defined by the observationType.

```json
{
    "@iot.id": 1,
    "@iot.selfLink": "http://example.org/v1.0/Observations(1)",
    "FeatureOfInterest@iot.navigationLink": "Observations(1)/FeatureOfInterest",
    "Datastream@iot.navigationLink":"Observations(1)/Datastream",
    "phenomenonTime": "2014-12-31T11:59:59.00+08:00",
    "resultTime": "2014-12-31T11:59:59.00+08:00",
    "result": 70.4
}
```

**8.2.8 FeatureOfInterest**

<table>
<thead>
<tr>
<th><strong>Requirements Class</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest">http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest</a></strong></td>
<td></td>
</tr>
<tr>
<td><strong>Target Type</strong></td>
<td>Web Service</td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/properties</a></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/relations</a></td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a></td>
</tr>
</tbody>
</table>

An Observation results in a value being assigned to a phenomenon. The phenomenon is a property of a feature, the latter being the FeatureOfInterest of the Observation [OGC and ISO 19156:2001]. In the context of the Internet of Things, many Observations’ FeatureOfInterest can be the Location of the Thing. For example, the FeatureOfInterest of a wifi-connect thermostat can be the Location of the thermostat (i.e., the living room where the thermostat is located in). In the case of remote sensing, the FeatureOfInterest can be the geographical area or volume that is being sensed.
Req 17 Each FeatureOfInterest entity SHALL have the mandatory properties listed in Table 20.

http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/properties

Req 18 Each FeatureOfInterest entity SHALL have the direct relation between a FeatureOfInterest entity and other entity types listed in Table 21.

http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/relations

### Table 20 Properties of a FeatureOfInterest entity

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>A property provides a label for FeatureOfInterest entity, commonly a descriptive name.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>description</td>
<td>The description about the FeatureOfInterest.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>encodingType</td>
<td>The encoding type of the feature property. Its value is one of the ValueCode enumeration (see Table 7 for the available ValueCode).</td>
<td>ValueCode</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>feature</td>
<td>The detailed description of the feature. The data type is defined by encodingType.</td>
<td>Any</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

### Table 21 Direct relation between a FeatureOfInterest entity and other entity types

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>One mandatory to many optional</td>
<td>An Observation observes on one-and-only-one FeatureOfInterest. One FeatureOfInterest could be observed by zero-to-many Observations.</td>
</tr>
</tbody>
</table>

### Example 8 an example of a FeatureOfInterest entity

```json
{
    "@iot.id": 1,
    "@iot.selfLink": "http://example.org/v1.0/FeaturesOfInterest(1)",
    "Observations@iot.navigationLink": "FeaturesOfInterest(1)/Observations",
    "name": "Weather Station YYC.",
    "description": "This is a weather station located at the Calgary Airport.",
    "encodingType": "application/vnd.geo+json",
    "feature": {
        "type": "Feature",
        "geometry": {
            "type": "Point",
            "coordinates": [-114.06,51.05]
        }
    }
}
```
9. SensorThings Service Interface

An OGC SensorThings API service exposes a service document resources that describe its data model. The service document lists the entity sets that can be CRUD. SensorThings API clients can use the service document to navigate the available entities in a hypermedia-driven fashion.

9.1 URI Components

The OGC SensorThings API service groups the same types of entities into entity sets. Each entity has a unique identifier and one-to-many properties. Also, in the case of an entity holding a relationship with entities in other entity sets, this type of relationship is expressed with navigation properties (i.e., navigationLink and associationLink).

Therefore, in order to perform CRUD actions on the resources, the first step is to address to the target resource(s) through URI. There are three major URI components used here, namely (1) the service root URI, (2) the resource path, and (3) the query options. In addition, the service root URI consists of two parts: (1) the location of the SensorThings service and (2) the version number. The version number follows the format indicated below:

"v"majorversionnumber + "." + minorversionnumber

Example 9 complete URI example

http://example.org/v1.0/Observations?$orderby=ID&$top=10

<table>
<thead>
<tr>
<th>service root URI</th>
<th>resource path</th>
<th>query options</th>
</tr>
</thead>
</table>

By attaching the resource path after the service root URI, clients can address to different types of resources such as an entity set, an entity, a property, or a navigation property. Finally, clients can apply query options after the resource path to further process the addressed resources, such as sorting by properties or filtering with criteria.

9.2 Resource Path

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path">http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path</a></td>
</tr>
</tbody>
</table>
The resource path comes right after the service root URI and can be used to address to different resources. The following lists the usages of the resource path.

**Req 19** An OGC SensorThings API service SHALL support all the resource path usages listed in Section 9.2.

http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path/resource-path-to-entities

### 9.2.1 Usage 1: no resource path

**URI Pattern:** SERVICE_ROOT_URI

**Response:** A JSON object with a property named value. The value of the property SHALL be a JSON Array containing one element for each entity set of the SensorThings Service.

Each element SHALL be a JSON object with at least two name/value pairs, one with name name containing the name of the entity set (e.g., Things, Locations, Datastreams, Observations, ObservedProperties and Sensors) and one with name url containing the URL of the entity set, which may be an absolute or a relative URL.

[Adapted from OData 4.0-JSON-Format section 5]

**Example 10** a SensorThings request with no resource path

**Example Request:** [http://example.org/v1.0/](http://example.org/v1.0/)

**Example Response:**
9.2.2 Usage 2: address to a collection of entities

To address to an entity set, users can simply put the entity set name after the service root URI. The service returns a JSON object with a property of value. The value of the property SHALL be a list of the entities in the specified entity set.

**URI Pattern:** SERVICE_ROOT_URI/ENTITY_SET_NAME

**Response:** A list of all entities (with all the properties) in the specified entity set when there is no service-driven pagination imposed. The response is represented as a JSON object containing a name/value pair named value. The value of the value name/value pair is a JSON array where each element is representation of an entity or a representation of an entity reference. An empty collection is represented as an empty JSON array.

The count annotation represents the number of entities in the collection. If present, it comes before the value name/value pair.

When there is service-driven pagination imposed, the nextLink annotation is included in a response that represents a partial result.

[Adapted from OData 4.0-JSON-Format section 12]
9.2.3 Usage 3: address to an entity in a collection

Users can address to a specific entity in an entity set by placing the unique identifier of the entity between brace symbol "()" and put after the entity set name. The service then returns the entity with all its properties.

**URI Pattern:** SERVICE_ROOT_URI/ENTITY_SET_NAME(ID_OF_THE_ENTITY)

**Response:** A JSON object of the entity (with all its properties) that holds the specified id in the entity set.

Example 12: an example request that addresses to an entity in a collection

Example Request: http://example.org/v1.0/Things(1)

9.2.4 Usage 4: address to a property of an entity

Users can address to a property of an entity by specifying the property name after the URI addressing to the entity. The service then returns the value of the specified property. If the property has a complex type value, properties of that value can be addressed by further property name composition.
If the property is single-valued and has the null value, the service SHALL respond with 204 No Content. If the property is not available, for example due to permissions, the service SHALL respond with 404 Not Found.

[Adapted from OData 4.0-Protocol 11.2.3]

**URI Pattern:** `SERVICE_ROOT_URI/RESOURCE_PATH_TO_AN_ENTITY/PROPERTY_NAME`

**Response:** The specified property of an entity that holds the id in the entity set.

**Example 13:** an example to address to a property of an entity

**Example Request:** `http://example.org/v1.0/Observations(1)/resultTime`

**Example Response:**

```json
{
    "resultTime": "2010-12-23T10:00:07:00"
}
```

9.2.5 **Usage 5: address to the value of an entity’s property**

To address the raw value of a primitive property, clients append a path segment containing the string `$value` to the property URL.

The default format for `TM_Object` types is `text/plain` using the ISO8601 format, such as `2014-03-01T13:00:00Z/2015-05-11T15:30:00Z` for `TM_Period` and `2014-03-01T13:00:02Z` for `TM_Instant`.

**URI Pattern:**

`SERVICE_ROOT_URI/ENTITY_SET_NAME(ID_OF_THE_ENTITY)/PROPERTY_NAME/$value`

**Response:** The raw value of the specified property of an entity that holds the id in the entity set.

**Example 14:** an example of addressing to the value of an entity’s property

**Example:** `http://example.org/v1.0/Observations(1)/resultTime/$value`

**Example Response:**

`2015-01-12T23:00:13-07:00`
9.2.6 Usage 6: address to a navigation property (navigationLink)

As the entities in different entity sets may hold some relationships, users can request the linked entities by addressing to a navigation property of an entity. The service then returns one or many entities that hold a certain relationship with the specified entity.

URI Pattern: SERVICE_ROOT_URI/ENTITY_SET_NAME(ID_OF_THE_ENTITY)/LINK_NAME

Response: A JSON object of one entity or a JSON array of many entities that holds a certain relationship with the specified entity.

Example 15: an example request addressing to a navigational property

Example: http://example.org/v1.0/Datastreams(1)/Observations returns all the Observations in the Datastream that holds the id 1.

9.2.7 Usage 7: address to an associationLink

As the entities in different entity sets may hold some relationships, users can request the linked entities’ selfLinks by addressing to an association link of an entity. An associationLink can be used to retrieve a reference to an entity or an entity set related to the current entity. Only the selfLinks of related entities are returned when resolving associationLinks.

URI Pattern: SERVICE_ROOT_URI/ENTITY_SET_NAME(KEY_OF_THE_ENTITY)/LINK_NAME/$ref

Response: A JSON object with a value property. The value of the value property is a JSON array containing one element for each associationLink. Each element is a JSON object with a name/value pairs. The name is url and the value is the selfLinks of the related entities.

Example 16: an example of addressing to an association link

Example Request: http://example.org/v1.0/Datastreams(1)/Observations/$ref returns all the selfLinks of the Observations of Datastream(1).

Example Response:

```json
{
  "value": [
    {
      "@iot.selfLinks": "http://example.org/v1.0/Observations(1)"
    },
    {
      "@iot.selfLinks": "http://example.org/v1.0/Observations(2)"
    }
  ]
}
```
9.2.8 Usage 8: nested resource path

As users can use navigation properties to link from one entity set to another, users can further extend the resource path with unique identifiers, properties, or links (i.e., Usage 3, 4 and 6).

Example 17: examples of nested resource path

Example Request 1: http://example.org/v1.0/Datastreams(1)/Observations(1) returns a specific Observation entity in the Datastream.

Example Request 2: http://example.org/v1.0/Datastreams(1)/Observations(1)/resultTime turns the resultTime property of the specified Observation in the Datastream.

Example Request 3: http://example.org/v1.0/Datastreams(1)/Observations(1)/FeatureOfInterest returns the FeatureOfInterest entity of the specified Observation in the Datastream.

9.3 Requesting Data

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data</a></td>
</tr>
<tr>
<td><strong>Target Type</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
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<td><strong>Requirement</strong></td>
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<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
</tbody>
</table>
Clients issue HTTP *GET* requests to OGC SensorThings API services for data. The resource path of the URL specifies the target of the request. Additional query operators can be specified through query options that are presented as follows. The query operators are prefixed with a dollar ($) character and specified as key-value pairs after the question symbol (?) in the request URI. Many of the OGC SensorThings API’s query options are adapted from OData’s query options. OData developers should be able to pick up SensorThings API query options very quickly.

**Req 20** OGC SensorThings API services are hypermedia driven services that return URLs to the client. If a client subsequently requests the advertised resource and the URL has expired, then the service SHALL respond with 410 *Gone*. If this is not feasible, the service SHALL respond with 404 *Not Found*.

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/status-code

**Req 21** If a service does not support a system query option, it SHALL fail any request that contains the unsupported option and SHALL return 501 *Not Implemented*.

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/query-status-code

### 9.3.1 Evaluating System Query Options

**Req 22** An OGC SensorThings API service SHALL evaluate the system query options following the order specified in Section 9.3.1.

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/order
The OGC SensorThings API adapts many of OData’s system query options and their usage. These query options allow refining the request.

The result of the service request is as if the system query options were evaluated in the following order.

Prior to applying any server-driven pagination:

- $filter
- $count
- $orderby
- $skip
- $top

After applying any server-driven pagination:

- $expand
- $select

9.3.2 Specifying Properties to Return

The $select and $expand system query options enable the client to specify the set of properties to be included in a response.

9.3.2.1 $expand

Req 23 The $expand system query option indicates the related entities to be represented inline. The value of the $expand query option SHALL be a comma separated list of navigation property names. Additionally, each navigation property can be followed by a forward slash and another navigation property to enable identifying a multi-level relationship.

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/expand

Example 18: examples of $expand query option

Example Request 1: http://example.org/v1.0/Things?$expand=Datastreams returns the entity set of Things as well as each of the Datastreams associated with each Thing entity.
Example Request 1 Response:

```json
{
  "values" : [
    {
      "@iot.id": 1,
      "@iot.selfLink": "http://example.org/v1.0/Things(1)",
      "Locations@iot.navigationLink": "Things(1)/Locations",
      "Datastreams@iot.count": 1,
      "Datastreams": [
        {
          "@iot.id": 1,
          "@iot.selfLink": "http://example.org/v1.0/Datastreams(1)",
          "name": "oven temperature",
          "description": "This is a datastream measuring the air temperature in an oven.",
          "unitOfMeasurement": {
            "name": "degree Celsius",
            "symbol": "°C",
            "definition": "http://unitsofmeasure.org/ucum.html#para-30"
          },
          "observationType": "http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement",
          "observedArea": {
            "type": "Polygon",
            "coordinates": [[[100,0],[101,0],[101,1],[100,1],[100,0]]]
          },
          "phenomenonTime": "2014-03-01T13:00:00Z/2015-05-11T15:30:00Z",
          "resultTime": "2014-03-01T13:00:00Z/2015-05-11T15:30:00Z"
        }
      ],
      "HistoricalLocations@iot.navigationLink": "Things(1)/HistoricalLocations",
      "description": "This thing is a convection oven.",
      "name": "Oven",
      "properties": {
        "owner": "John Doe",
        "color": "Silver"
      }
    }
  ]
}
```

Example Request 2:
http://example.org/v1.0/Things?$expand=Datastreams/ObservedProperty returns the collection of Things, the Datastreams associated with each Thing, and the ObservedProperty associated with each Datastream.

Example Request 3:
http://example.org/v1.0/Datastreams(1)?$expand=Observations,ObservedProperty returns the Datastream whose id is 1 as well as the Observations and ObservedProperty associated with this Datastream.

Query options can be applied to the expanded navigation property by appending a semicolon-separated list of query options, enclosed in parentheses, to the navigation property name. Allowed system query options are $filter, $select, $ orderby, $skip, $top, $count, and $expand.

[Adapted from OData 4.0- URL 5.1.2]
Example Request 4:  
http://example.org/v1.0/Datastreams(1)?$expand=Observations($filter=result eq 1) returns the Datastream whose id is 1 as well as its Observations with a result equal to 1.

9.3.2.2 $select

Req 24 The $select system query option requests the service to return only the properties explicitly requested by the client. The value of a $select query option SHALL be a comma-separated list of selection clauses. Each selection clause SHALL be a property name (including navigation property names). In the response, the service SHALL return the specified content, if available, along with any available expanded navigation properties.

[Adapted from OData 4.0-Protocol 11.2.4.1]

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/select

Example 19: examples of $select query option

Example Request 1:  
http://example.org/v1.0/Observations?$select=result,resultTime returns only the result and resultTime properties for each Observation entity.

Example Request 2:  
http://example.org/v1.0/Datastreams(1)?$select=id,Observations&$expand=Observations/FeatureOfInterest returns the id property of the Datastream entity, and all the properties of the entity identified by the Observations and FeatureOfInterest navigation properties.

Example Request 3:  
http://example.org/v1.0/Datastreams(1)?$expand=Observations($select=result) returns the Datastream whose id is 1 as well as the result property of the entity identified by the Observations navigation property.

9.3.3 Query Entity Sets

9.3.3.1 $orderby

Req 25 The $orderby system query option specifies the order in which items are returned from the service. The value of the $orderby system query option SHALL contain a comma-separated list of expressions whose primitive result values are used to sort the items. A special case of such an expression is a property path terminating on a primitive property. A type cast using the qualified entity type name SHALL be ordered by a property defined on a derived type.

The expression MAY include the suffix asc for ascending or desc for descending, separated from the property name by one or more spaces. If asc or desc is not specified, the service SHALL order by the specified property in ascending order.
Null values SHALL come before non-null values when sorting in ascending order and after non-null values when sorting in descending order.

Items SHALL be sorted by the result values of the first expression, and then items with the same value for the first expression SHALL be sorted by the result value of the second expression, and so on.

[Note: Adapted from OData 4.0-Protocol 11.2.5.2]

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/orderby

Example 20: examples of $orderby query option

Example Request 1: http://example.org/v1.0/Observations?$orderby=result returns all Observations ordered by the result property in ascending order.

Example Request 2: http://example.org/v1.0/Observations?$expand=Datastream&$orderby=Datastreams/id desc, phenomenonTime returns all Observations ordered by the id property of the linked Datastream entry in descending order, then by the phenomenonTime property of Observations in ascending order.

9.3.3.2 $top

Req 26 The $top system query option specifies the limit on the number of items returned from a collection of entities. The value of the $top system query option SHALL be a non-negative integer n. The service SHALL return the number of available items up to but not greater than the specified value n.

If no unique ordering is imposed through an $orderby query option, the service SHALL impose a stable ordering across requests that include $top.

[Note: Adapted from OData 4.0-Protocol 11.2.5.3]

In addition, if the $top value exceeds the service-driven pagination limitation (i.e., the largest number of entities the service can return in a single response), the $top query option SHALL be discarded and the server-side pagination limitation SHALL be imposed.

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/top

Example 21: examples of $top query option

Example Request 1: http://example.org/v1.0/Things?$top=5 returns only the first five entities in the Things collection.
Example Request 2: 
http://example.org/v1.0/Observations?$top=5&$orderby=phenomenonTime_desc
returns the first five Observation entries after sorted by the phenomenonTime property in descending order.

9.3.3.3 $skip

Req 27 The $skip system query option specifies the number for the items of the queried collection that SHALL be excluded from the result. The value of $skip system query option SHALL be a non-negative integer n. The service SHALL return items starting at position n+1.

Where $top and $skip are used together, $skip SHALL be applied before $top, regardless of the order in which they appear in the request.

If no unique ordering is imposed through an $orderby query option, the service SHALL impose a stable ordering across requests that include $skip.

[Note: Adapted from OData 4.0 - Protocol 11.2.5.4]

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/skip

Example 22: examples of $skip query option

Example Request 1: http://example.org/v1.0/Things?$skip=5 returns Thing entities starting with the sixth Thing entity in the Things collection.

Example Request 2:  
http://example.org/v1.0/Observations?$skip=2&$top=2&$orderby=resultTime  returns the third and fourth Observation entities from the collection of all Observation entities when the collection is sorted by the resultTime property in ascending order.

9.3.3.4 $count

Req 28 The $count system query option with a value of true specifies that the total count of items within a collection matching the request SHALL be returned along with the result. A $count query option with a value of false (or not specified) hints that the service SHALL not return a count.

The service SHALL return an HTTP Status code of 400 Bad Request if a value other than true or false is specified.

The $count system query option SHALL ignore any $top, $skip, or $expand query options, and SHALL return the total count of results across all pages including only those results matching any specified $filter. Clients should be aware that the count returned inline may not exactly equal the actual number of items returned, due to latency between calculating the count and enumerating the last value or due to inexact calculations on the service.
Example 23: examples of $count query option

Example Request 1: [http://example.org/v1.0/Things?$count=true](http://example.org/v1.0/Things?$count=true) return, along with the results, the total number of Things in the collection.

Example Response:

```json
{
    "@iot.count": 2,
    "value": [
        {...},
        {...}
    ]
}
```

9.3.3.5 $filter

Req 29 The $filter system query option allows clients to filter a collection of entities that are addressed by a request URL. The expression specified with $filter is evaluated for each entity in the collection, and only items where the expression evaluates to true SHALL be included in the response. Entities for which the expression evaluates to false or to null, or which reference properties that are unavailable due to permissions, SHALL be omitted from the response.

[Adapted from Data 4.0-URL Conventions 5.1.1]

The expression language that is used in $filter operators SHALL support references to properties and literals. The literal values SHALL be strings enclosed in single quotes, numbers and boolean values (true or false) or datetime values represented as ISO 8601 time string.

[http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/filter](http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/filter)

Example 24: examples of $filter query option

Example Request 1: [http://example.org/v1.0/Observations?$filter=result lt 10.00](http://example.org/v1.0/Observations?$filter=result lt 10.00) returns all Observations whose result is less than 10.00.

In addition, clients can choose to use the properties of linked entities in the $filter predicate. The following are examples of the possible uses of the $filter in the data model of the SensorThings service.
Example Request 2: \( \text{http://example.org/v1.0/Observations?$filter=} \text{Datastream/id eq '1'} \) returns all Observations whose Datastream's id is 1.

Example Request 3:
\( \text{http://example.org/v1.0/Things?$filter=} \text{geo.distance(Locations/location, geog'POINT(-122, 43)')} \text{ gt 1} \) returns Things that the distance between their last known locations and POINT(-122 43) is greater than 1.

Example Request 4:
\( \text{http://example.org/v1.0/Things?$expand=} \text{Datastreams/Observations/FeatureOfInterest} \text{&$filter=} \text{Datastreams/Observations/FeatureOfInterest/id eq 'FOI_1' and Datastreams/Observations/resultTime ge 2010-06-01T00:00:00Z and Datastreams/Observations/resultTime le 2010-07-01T00:00:00Z} \) returns Things that have any observations of a feature of interest with a unique identifier equals to 'FOI_1' in June 2010.

### 9.3.3.5.1 Built-in filter operations

The OGC SensorThings API supports a set of built-in filter operations, as described in the following table. These built-in filter operator usages and definitions follow the [OData Specification Section 11.2.5.1.1] and [OData Version 4.0 ABNF].

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>eq</td>
<td>Equal</td>
<td>/ObservedProperties?$filter=unitOfMeasurement/name eq 'degree Celsius'</td>
</tr>
<tr>
<td>ne</td>
<td>Not equal</td>
<td>/ObservedProperties?$filter=unitOfMeasurement/name ne 'degree Celsius'</td>
</tr>
<tr>
<td>gt</td>
<td>Greater than</td>
<td>/Observations?$filter=result gt 20.0</td>
</tr>
<tr>
<td>ge</td>
<td>Greater than or equal</td>
<td>/Observations?$filter=result ge 20.0</td>
</tr>
<tr>
<td>lt</td>
<td>Less than</td>
<td>/Observations?$filter=result lt 100</td>
</tr>
<tr>
<td>le</td>
<td>Less than or equal</td>
<td>/Observations?$filter=result le 100</td>
</tr>
<tr>
<td>and</td>
<td>Logical and</td>
<td>/Observations?$filter=result le 3.5 and FeatureOfInterest/id eq '1'</td>
</tr>
<tr>
<td>or</td>
<td>Logical or</td>
<td>/Observations?$filter=result gt 20 or result le 3.5</td>
</tr>
<tr>
<td>not</td>
<td>Logical negation</td>
<td>/Things?$filter=not startswith(description,'test')</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>add</td>
<td>Addition</td>
<td>/Observations?$filter=result add 5 gt 10</td>
</tr>
<tr>
<td>sub</td>
<td>Subtraction</td>
<td>/Observations?$filter=result sub 5 gt 10</td>
</tr>
<tr>
<td>mul</td>
<td>Multiplication</td>
<td>/Observations?$filter=result mul 2 gt 2000</td>
</tr>
<tr>
<td>div</td>
<td>Division</td>
<td>/Observations?$filter=result div 2 gt 4</td>
</tr>
<tr>
<td>mod</td>
<td>Modulo</td>
<td>/Observations?$filter=result mod 2 eq 0</td>
</tr>
</tbody>
</table>
9.3.3.5.2 Built-in query functions

The OGC SensorThings API supports a set of functions that can be used with the $filter or $orderby query operations. The following table lists the available functions and they follow the OData Canonical function definitions listed in Section 5.1.1.4 of the [OData Version 4.0 Part 2: URL Conventions] and the syntax rules for these functions are defined in [OData Version 4.0 ABNF].

In order to support spatial relationship functions, SensorThings API defines nine additional geospatial functions based on the spatial relationship between two geometry objects. The spatial relationship functions are defined in the OGC Simple Feature Access specification [OGC 06-104r4 part 1, clause 6.1.2.3]. The names of these nine functions start with a prefix "st_" following the OGC Simple Feature Access specification [OGC 06-104r4]. In addition, the Well-Known Text (WKT) format is the default input geometry for these nine functions.

<table>
<thead>
<tr>
<th>Req 31</th>
<th>The built-in query functions SHALL be as defined in Table 23.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/built-in-query-functions">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/built-in-query-functions</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>String Functions</strong></td>
<td></td>
</tr>
<tr>
<td>bool substringof(string p0, string p1)</td>
<td>substringof('Sensor Things',description)</td>
</tr>
<tr>
<td>bool endswith(string p0, string p1)</td>
<td>endswith(description,'Things')</td>
</tr>
<tr>
<td>bool startswith(string p0, string p1)</td>
<td>startswith(description,'Sensor')</td>
</tr>
<tr>
<td>int length(string p0)</td>
<td>length(description) eq 13</td>
</tr>
<tr>
<td>int indexof(string p0, string p1)</td>
<td>indexof(description,'Sensor') eq 1</td>
</tr>
<tr>
<td>string substring(string p0, int p1)</td>
<td>substring(description,1) eq 'ensor Things'</td>
</tr>
</tbody>
</table>
### String Functions

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tolower(string p0)</code></td>
<td><code>tolower(description)</code> eq 'sensor things'</td>
</tr>
<tr>
<td><code>toupper(string p0)</code></td>
<td><code>toupper(description)</code> eq 'SENSOR THINGS'</td>
</tr>
<tr>
<td><code>trim(string p0)</code></td>
<td><code>trim(description)</code> eq 'Sensor Things'</td>
</tr>
<tr>
<td><code>concat(string p0, string p1)</code></td>
<td><code>concat(concat(unitOfMeasurement/symbol,', ', unitOfMeasurement/name) eq 'degree, Celsius'</code></td>
</tr>
</tbody>
</table>

### Date Functions

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>year(resultTime)</code></td>
<td><code>year(resultTime)</code> eq 2015</td>
</tr>
<tr>
<td><code>month(resultTime)</code></td>
<td><code>month(resultTime)</code> eq 12</td>
</tr>
<tr>
<td><code>day(resultTime)</code></td>
<td><code>day(resultTime)</code> eq 8</td>
</tr>
<tr>
<td><code>hour(resultTime)</code></td>
<td><code>hour(resultTime)</code> eq 1</td>
</tr>
<tr>
<td><code>minute(resultTime)</code></td>
<td><code>minute(resultTime)</code> eq 0</td>
</tr>
<tr>
<td><code>second(resultTime)</code></td>
<td><code>second(resultTime)</code> eq 0</td>
</tr>
<tr>
<td><code>fractionalseconds(resultTime)</code></td>
<td><code>second(resultTime)</code> eq 0</td>
</tr>
<tr>
<td><code>date(resultTime)</code></td>
<td><code>date(resultTime)</code> ne date(validTime)</td>
</tr>
<tr>
<td><code>time(resultTime)</code></td>
<td><code>time(resultTime)</code> le validTime</td>
</tr>
<tr>
<td><code>totaloffsetminutes(resultTime)</code></td>
<td><code>totaloffsetminutes(resultTime)</code> eq 60</td>
</tr>
<tr>
<td><code>now()</code></td>
<td><code>resultTime</code> ge <code>now()</code></td>
</tr>
<tr>
<td><code>mindatetime()</code></td>
<td><code>resultTime</code> eq <code>mindatetime()</code></td>
</tr>
<tr>
<td><code>maxdatetime()</code></td>
<td><code>resultTime</code> eq <code>maxdatetime()</code></td>
</tr>
</tbody>
</table>

### Math Functions

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>round(result)</code></td>
<td><code>round(result)</code> eq 32</td>
</tr>
<tr>
<td><code>floor(result)</code></td>
<td><code>floor(result)</code> eq 32</td>
</tr>
<tr>
<td><code>ceiling(result)</code></td>
<td><code>ceiling(result)</code> eq 33</td>
</tr>
</tbody>
</table>

### Geospatial Functions

<table>
<thead>
<tr>
<th>Function Call</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>geo.distance(Point p0, Point p1)</code></td>
<td><code>geo.distance(location, geography'POINT (30 10) ')</code></td>
</tr>
<tr>
<td><code>geo.length(LineString p0)</code></td>
<td><code>geo.length(geography'LINESTRING (30 10, 10 30, 40 40) ')</code></td>
</tr>
<tr>
<td><code>geo.intersects(Point p0, Polygon p1)</code></td>
<td><code>geo.intersects(location, geography'POLYGON ((30 10, 20 20, 20 40, 40 40, 30 10))')</code></td>
</tr>
</tbody>
</table>
Spatial Relationship Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bool st_equals</td>
<td>st_equals(location, geography'POINT (30 10)')</td>
</tr>
<tr>
<td>bool st_disjoint</td>
<td>st_disjoint(location, geography'POLYGON ((30 10, 10 20, 20 40, 40 40, 30 10))')</td>
</tr>
<tr>
<td>bool st_touches</td>
<td>st_touches(location, geography'LINESTRING (30 10, 10 30, 40 40)')</td>
</tr>
<tr>
<td>bool st_within</td>
<td>st_within(location, geography'POLYGON ((30 10, 10 20, 20 40, 40 40, 30 10))')</td>
</tr>
<tr>
<td>bool st_overlaps</td>
<td>st_overlaps(location, geography'POLYGON ((30 10, 10 20, 20 40, 40 40, 30 10))')</td>
</tr>
<tr>
<td>bool st_crosses</td>
<td>st_crosses(location, geography'LINESTRING (30 10, 10 30, 40 40)')</td>
</tr>
<tr>
<td>bool st_intersects</td>
<td>st_intersects(location, geography'LINESTRING (30 10, 10 30, 40 40)')</td>
</tr>
<tr>
<td>bool st_contains</td>
<td>st_contains(location, geography'POINT (30 10)')</td>
</tr>
<tr>
<td>bool st_relate</td>
<td>st_relate(location, geography'POLYGON ((30 10, 10 20, 20 40, 40 40, 30 10))', 'T********')</td>
</tr>
</tbody>
</table>

9.3.3.6 Server-Driven Paging (nextLink)

Req 32 Responses that include only a partial set of the items identified by the request URL SHALL contain a link that allows retrieving the next partial set of items. This link is called a nextLink; its representation is format-specific. The final partial set of items SHALL NOT contain a nextLink.

The nextLink annotation indicates that a response is only a subset of the requested collection of entities or collection of entity references. It contains a URL that allows retrieving the next subset of the requested collection.

SensorThings clients SHALL treat the URL of the nextLink as opaque, and SHALL NOT append system query options to the URL of a next link. Services may not allow a change of format on requests for subsequent pages using the next link.

[Adapted from OData 4.0-Protocol 11.2.5.7]

http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/pagination

Example 25: http://example.org/v1.0/Things returns a subset of the Thing entities of requested collection of Things. The nextLink contains a link allowing retrieving the next partial set of items.
10. SensorThings Sensing Create-Update-Delete

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/link-to-existing-entities">link-to-existing-entities</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert">deep-insert</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert-status-code">deep-insert-status-code</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/update-entity">update-entity</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/delete-entity">delete-entity</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://docs.oasis-open.org/odata/odata/v4.0/errata02/os/complete/part1-protocol/odata-v4.0-errata02-os-part1-protocol-complete.html#_Toc406398328">protocol</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://docs.oasis-open.org/odata/odata/v4.0/errata02/os/complete/part1-protocol/odata-v4.0-errata02-os-part1-protocol-complete.html#_Toc406398329">protocol</a></td>
</tr>
</tbody>
</table>

10.1 Overview
As many IoT devices are resource-constrained, the SensorThings API adopts the efficient REST web service style. That means the Create, Update, Delete actions can be performed
on the SensorThings entity types. The following subsection explains the Create, Update, and Delete protocol.

10.2 Create an entity

Req 33  To create an entity in a collection, the client SHALL send a HTTP POST request to that collection's URL. The POST body SHALL contain a single valid entity representation.

If the target URL for the collection is a navigationLink, the new entity is automatically linked to the entity containing the navigationLink.

Upon successful completion, the response SHALL contain a HTTP location header that contains the selfLink of the created entity.

Upon successful completion the service SHALL respond with either 201 Created, or 204 No Content.

[Adapted from Data 4.0-Protocol, 11.4.2 Create an Entity]

In addition, the link between entities SHALL be established upon creating an entity. Two use cases SHALL be considered: (1) link to existing entities when creating an entity, and (2) create related entities when creating an entity. The requests for these two use cases are described in the following subsection.

When clients create resources in a SensorThings service, they SHALL follow the integrity constraints listed in Table 24. For example, a Datastream entity SHALL link to a Thing entity. When a client wants to create a Datastream entity, the client needs to either (1) create a linked Thing entity in the same request or (2) link to an already created Thing entity. The complete integrity constraints for creating resources are shown in the following table.

Special case #1 - When creating an Observation entity that links to a FeatureOfInterest entity: Sometimes the FeatureOfInterest of an Observation is the Location of the Thing. For example, a wifi-connected thermostat’s temperature observation’s feature-of-interest can be the location of the smart thermostat, that is the room where the smart thermostat is located in.

In this case, when a client creates an Observation entity, the client SHOULD omit the link to a FeatureOfInterest entity in the POST body message and SHOULD not create a related FeatureOfInterest entity with deep insert. And if the service detects that there is no link to a FeatureOfInterest entity in the POST body message that creates an Observation entity, the service SHALL either (1) create a FeatureOfInterest entity by using the location property from the Location of the Thing entity when there is no FeatureOfInterest whose location property is from the Location of the Thing entity or (2) link to the FeatureOfInterest whose location property is from the Location of the Thing entity.

Special case #2: In the context of IoT, many Observations’ resultTime and phenomenonTime cannot be distinguished or the resultTime is not available. In this case, when a client creates an Observation entity, the client MAY omit the resultTime and the service SHOULD assign a null value to the resultTime.
Table 24 Integrity constraints when creating an entity

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Integrity Constraints</th>
</tr>
</thead>
</table>

http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/create-entity
Create a **Thing** entity

Create a **Location** entity

Create a **Datastream** entity

Create a **Sensor** entity

Create an **ObservedProperty** entity

Create an **Observation** entity

Create a **FeatureOfInterest** entity

<table>
<thead>
<tr>
<th>Operation</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a <strong>Thing</strong> entity</td>
<td>-</td>
</tr>
<tr>
<td>Create a <strong>Location</strong> entity</td>
<td>-</td>
</tr>
<tr>
<td>Create a <strong>Datastream</strong> entity</td>
<td>SHALL link to a <strong>Thing</strong> entity.</td>
</tr>
<tr>
<td></td>
<td>SHALL link to a <strong>Sensor</strong> entity</td>
</tr>
<tr>
<td></td>
<td>SHALL link to an <strong>ObservedProperty</strong> entity.</td>
</tr>
<tr>
<td>Create a <strong>Sensor</strong> entity</td>
<td>-</td>
</tr>
<tr>
<td>Create an <strong>ObservedProperty</strong> entity</td>
<td>-</td>
</tr>
<tr>
<td>Create an <strong>Observation</strong> entity</td>
<td>SHALL link to a <strong>Datastream</strong> entity.</td>
</tr>
<tr>
<td></td>
<td>SHALL link to a <strong>FeatureOfInterest</strong> entity. If no link specified, the service SHALL create a <strong>FeatureOfInterest</strong> entity from the content of the <strong>Location</strong> entities.</td>
</tr>
<tr>
<td>Create a <strong>FeatureOfInterest</strong> entity</td>
<td>-</td>
</tr>
</tbody>
</table>

### 10.2.1 Request

HTTP Method: POST

URI Pattern: SERVICE_ROOT_URI/COLLECTION_NAME

Header: Content-Type: application/json

Message Body: A single valid entity representation for the specified collection.

**Example 26: create a **Thing** entity**

```plaintext
POST /v1.0/Things HTTP/1.1
Host: example.org/
Content-Type: application/json

{
  "name": "thermostat",
  "description": "This is a smart thermostat with WiFi communication capabilities."
}
```
10.2.1.1 Link to existing entities when creating an entity

Req 34 A SensorThings API service, that supports entity creation, SHALL support linking new entities to existing entities upon creation. To create a new entity with links to existing entities in a single request, the client SHALL include the unique identifiers of the related entities associated with the corresponding navigation properties in the request body.

In the case of creating an Observation whose FeatureOfInterest is the Thing’s Location (that means the Thing entity has a related Location entity), the request of creating the Observation SHOULD NOT include a link to a FeatureOfInterest entity. The service will first automatically create a FeatureOfInterest entity from the Location of the Thing and then link to the Observation.

In the complex use case of a Thing has multiple Location representations, the service SHOULD decide the default Location encoding when an Observation’s FeatureOfInterest is the Thing’s Location.

http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/link-to-existing-entities

Example 27: create an Observation entity, which links to an existing Sensor entity (whose id is 1), an existing FeatureOfInterest entity (whose id is 2).

```
POST /v1.0/Observations HTTP/1.1
Host: example.org/
Content-Type: application/json

{
    "Datastream": {
        "@iot.id": 1
    },
    "phenomenonTime": "2013-04-18T16:15:00-07:00",
    "result": 124,
    "FeatureOfInterest": {
        "@iot.id": 2
    }
}
```
10.2.1.2 Create related entities when creating an entity

Req 35 A request to create an entity that includes related entities, represented using the appropriate inline representation, is referred to as a "deep insert". A SensorThings service that supports entity creation SHALL support deep insert.

If the inline representation contains a value for a computed property (i.e., id), the service SHALL ignore that value when creating the related entity.

On success, the service SHALL create all entities and relate them. On failure, the service SHALL NOT create any of the entities.

[Adapted from Data 4.0-Protocol 11.4.2.2]
http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert

Example 28: create a Thing while creating two related Sensors and one related Observation (which links to an existing FeatureOfInterest entity and an existing ObservedProperty entity).

```
POST /v1.0/Things HTTP/1.1
Host: example.org/
Content-Type: application/json

{
    "description": "This an oven with a temperature datastream.",
    "name": "oven",
    "Locations": [
        {
            "name": "CCIT",
            "description": "Calgary Centre for Innovative Technologies",
            "encodingType": "application/vnd.geo+json",
            "location": {
                "type": "Feature",
                "geometry": {
                    "type": "Point",
                    "coordinates": [10, 10]
                }
            }
        }
    ],
    "Datastreams": [
        {
            "name": "oven temperature",
            "description": "This is a datastream for an oven's internal temperature.",
            "unitOfMeasurement": {
                "name": "degree Celsius",
                "symbol": "°C",
                "definition": "http://unitsofmeasure.org/ucum.html#para-30"
            },
            "observationType": "http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_Measurement",
            "observedArea": {
                "type": "Polygon",
                "coordinates": [[100,0], [101,0], [101,1], [100,1], [100,0]]
            },
            "Observations": [
                {
                    "phenomenonTime": "2012-06-26T03:42:02-0600",
                }
            ]
        }
    ]
}
```
"result": 70.4,
"FeatureOfInterest": {
  "name": "CCIT #361",
  "description": "This is CCIT #361, Noah's dad's office",
  "encodingType": "application/vnd.geo+json",
  "feature": {
    "type": "Feature",
    "geometry": {
      "type": "Polygon",
      "coordinates": [
        [[100,50], [10,9], [23,4], [100,50]], [[30,20], [10,4], [4,22], [30,20]]
      ]
    }
  }
},
"ObservedProperty": {
  "name": "DewPoint Temperature",
  "definition": "http://sweet.jpl.nasa.gov/ontology/property.owl#DewPointTemperature",
  "description": "The dewpoint temperature is the temperature to which the air must be cooled, at constant pressure, for dew to form. As the grass and other objects near the ground cool to the dewpoint, some of the water vapor in the atmosphere condenses into liquid water on the objects."
},
"Sensor": {
  "name": "DS18B20",
  "description": "DS18B20 is an air temperature sensor…",
  "encodingType": "application/pdf",
}
]

10.2.2 Response

Upon successfully creating an entity, the service response SHALL contain a Location header that contains the URL of the created entity. Upon successful completion the service SHALL respond with 201 Created. Regarding all the HTTP status code, please refer to the HTTP Status Code section.

http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert-status-code

10.3 Update an entity

To update an entity in a collection a SensorThings service SHALL follow the requirements as defined in Section 10.3.

http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/update-entity

10.3.1 Request

In SensorThings PATCH is the preferred means of updating an entity. PATCH provides more resiliency between clients and services by directly modifying only those values specified by the client.
The semantics of PATCH, as defined in [RFC5789], are to merge the content in the request payload with the entity’s current state, applying the update only to those components specified in the request body. The properties provided in the payload corresponding to updatable properties SHALL replace the value of the corresponding property in the entity. Missing properties of the containing entity or complex property SHALL NOT be directly altered.

Services MAY additionally support PUT, but should be aware of the potential for data-loss in round-tripping properties that the client may not know about in advance, such as open or added properties, or properties not specified in metadata. Services that support PUT SHALL replace all values of structural properties with those specified in the request body. Omitting a non-nullable property with no service-generated or default value from a PUT request results in a 400 Bad Request error.

Key and other non-updatable properties that are not tied to key properties of the principal entity, can be omitted from the request. If the request contains a value for one of these properties, the service SHALL ignore that value when applying the update.

The service ignores entity id in the payload when applying the update.

The entity SHALL NOT contain related entities as inline content. It MAY contain binding information for navigation properties. For single-valued navigation properties this replaces the relationship. For collection-valued navigation properties this adds to the relationship.

On success, the response SHALL be a valid success response.

Services MAY additionally support JSON PATCH format [RFC6902] to express a sequence of operations to apply to a SensorThings entity.

[Adapted from OData 4.0-Protocol 11.4.3]

**HTTP Method**: PATCH or PUT

**URI Pattern**: An URI addressing to a single entity.

**Header**: Content-Type: application/json

**Message Body**: A single entity representation including a subset of properties for the specified collection.

**Example 29: update the Thing whose id is 1.**

```json
PATCH /v1.0/Things(1) HTTP/1.1
Host: example.org/
Content-Type: application/json

{
    "description":"This thing is an oven."
}
```
10.3.2 Response
On success, the response SHALL be a valid success response. In addition, when the client sends an update request to a valid URL where an entity does not exist, the service SHALL fail the request.

Upon successful completion, the service must respond with 200 OK or 204 No Content. Regarding all the HTTP status code, please refer to the HTTP Status Code section.

10.4 Delete an entity

<table>
<thead>
<tr>
<th>Req 38</th>
<th>To delete an entity in a collection a SensorThings service SHALL follow the requirements as defined in section 10.4.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/delete-entity">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/delete-entity</a></td>
</tr>
</tbody>
</table>

10.4.1 Request
A successful DELETE request to an entity’s edit URL deletes the entity. The request body SHOULD be empty.

Services SHALL implicitly remove relations to and from an entity when deleting it; clients need not delete the relations explicitly.

Services MAY implicitly delete or modify related entities if required by integrity constraints. Table 25 listed SensorThings API’s integrity constraints when deleting an entity.

HTTP Method: DELETE
URI Pattern: An URI addressing to a single entity.

Example 30: delete the Thing with unique identifier equals to 1

DELETE http://example.org/v1.0/Things(1)

Table 25 Integrity constraints when deleting an entity

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Integrity Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delete a Thing entity</td>
<td>Delete all the Datastream entities linked to the Thing entity.</td>
</tr>
<tr>
<td>Delete a Location entity</td>
<td>Delete all the HistoricalLocation entities linked to the Location entity</td>
</tr>
</tbody>
</table>
Delete a Datastream entity
Delete all the Observation entities linked to the Datastream entity.

Delete a Sensor entity
Delete all the Datastream entities linked to the Sensor entity.

Delete an ObservedProperty entity
Delete all the Datastream entities linked to the ObservedProperty entity.

Delete an Observation entity
- -

Delete a FeatureOfInterest entity
Delete all the Observation entities linked to the FeatureOfInterest entity.

Delete a HistoricalLocation entity
- -

11. Batch Requests

Requirements Class

http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request/batch-request">http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request/batch-request</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://docs.oasis-open.org/odata/odata/v4.0/errata02/os/complete/part1-protocol/odata-v4.0-errata02-os-part1-protocol-complete.html#_Toc406398359">http://docs.oasis-open.org/odata/odata/v4.0/errata02/os/complete/part1-protocol/odata-v4.0-errata02-os-part1-protocol-complete.html#_Toc406398359</a></td>
</tr>
</tbody>
</table>

Req 39 The batch-processing of the SensorThings service SHALL be as defined in Section 11.
http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request/batch-request

11.1 Introduction

The SensorThings service interface provides interfaces for users to perform CRUD actions on resources through different HTTP methods. However, as many IoT devices are resource-constrained, handling a large number of communications may not be practical. This section describes how a SensorThings service can support executing multiple operations sent in a single HTTP request through the use of batch processing. This section covers both how batch operations are represented and processed. SensorThings batch request extension is adapted from [OData 4.0 Protocol 11.7] and all subsections.
The only difference is that the OData-Version header SHOULD be omitted in SensorThings. Readers are encouraged to read the OData specification section 11.7 before reading the examples below.

11.2 Batch-processing request
A batch request is represented as a Multipart MIME v1.0 message [RFC2046], a standard format allowing the representation of multiple parts, each of which may have a different content type, within a single request.

The example below shows a GUID as a boundary and example.org/v1.0/ for the URI of the service.

Batch requests are submitted as a single HTTP POST request to the batch endpoint of a service, located at the URL $batch relative to the service root (e.g., example.org/v1.0/$batch).

Note: In the example, request bodies are excluded in favor of English descriptions inside '<>' brackets to simplify the example.

Example 31-1: A Batch Request header example

```
POST /v1.0/$batch HTTP/1.1
Host: example.org
Content-Type: multipart/mixed;boundary=batch_36522ad7-fc75-4b56-8c71-56071383e77b

<BATCH_REQUEST_BODY>
```

Note: The batch request boundary must be quoted if it contains any of the following special characters:

```
( ) < > @ , ; : / " [ ] ? =
```

11.2.1 Batch request body example
The following example shows a Batch Request that contains the following operations in the order listed

- A query request
- Change Set that contains the following requests:
  - Insert entity (with Content-ID = 1)
  - Update request (with Content-ID = 2)
- A second query request

Note: For brevity, in the example, request bodies are excluded in favor of English descriptions inside <> brackets.

Note also that the two empty lines after the Host header of the GET request are necessary: the first is part of the GET request header; the second is the empty body of the GET request, followed by a CRLF according to [RFC2046].
[Adapted from OData 4.0 Protocol 11.7.2]

Example 31-2: a Batch Request body example

```
POST /v1.0/$batch HTTP/1.1
Host: host
Content-Type: multipart/mixed;boundary=batch_36522ad7-fc75-4b56-8c71-56071383e77b
Content-Length: ###
--batch_36522ad7-fc75-4b56-8c71-56071383e77b
Content-Type: application/http
Content-Transfer-Encoding:binary

GET /v1.0/Things(1)
Host: host
--batch_36522ad7-fc75-4b56-8c71-56071383e77b
Content-Type: multipart/mixed;boundary=changeset_77162fcd-b8da-41ac-a9f8-9357efbbd

--changeset_77162fcd-b8da-41ac-a9f8-9357efbbd
Content-Type: application/http
Content-Transfer-Encoding: binary
Content-ID: 1

POST /v1.0/Things HTTP/1.1
Host: host
Content-Type: application/json
Content-Length: ###

<JSON representation of a new Thing>
--changeset_77162fcd-b8da-41ac-a9f8-9357efbbd

--changeset_77162fcd-b8da-41ac-a9f8-9357efbbd
Content-Type: application/http
Content-Transfer-Encoding: binary
Content-ID: 2

PATCH /v1.0/Things(1) HTTP/1.1
Host: host
Content-Type: application/json
If-Match: xxxxxx
Content-Length: ###

<JSON representation of Things(1)>
--changeset_77162fcd-b8da-41ac-a9f8-9357efbbd

GET /v1.0/Things(3) HTTP/1.1
Host: host
--batch_36522ad7-fc75-4b56-8c71-56071383e77b--
```

11.2.2 Referencing new entities in a change set example

Example 31-3: A Batch Request that contains the following operations in the order listed:

A change set that contains the following requests:

1. Insert a new Datastream entity (with Content-ID = 1)
2. Insert a second new entity, a Sensor entity in this example (reference request with Content-ID = 1)
11.3 Batch-processing response

Example 31-4: referencing the batch request example 31-2 above, assume all the requests except the final query request succeed. In this case the response would be:
11.4 Asynchronous batch requests

Example 31-5: referencing the example 31-2 above again, assume that when interrogating the monitor URL for the first time only the first request in the batch finished processing and all the remaining requests except the final query request succeed. In this case the response would be:

Client makes a second request using the returned monitor URL:
12. SensorThings MultiDatastream extension

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream">http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/properties">http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/properties</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/relations">http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/relations</a></td>
</tr>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/constraints">http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/constraints</a></td>
</tr>
</tbody>
</table>

Observation results may have many data types, including primitive types like category or measure, but also more complex types such as time, location and geometry [OGC 10-004r3 and ISO 19156:2011]. SensorThings' MultiDatastream entity is an extension to handle complex observations when the result is an array.

A MultiDatastream groups a collection of Observations and the Observations in a MultiDatastream have a complex result type.

The MultiDatastream extension entities are depicted in Figure 3.
Fig 3 MultiDatastream Extension Entities

Req 40 Each MultiDatastream entity SHALL have the mandatory properties and MAY have the optional properties listed in Table 26.

http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/properties

Req 41 Each MultiDatastream entity SHALL have the direct relation between a Datastream entity and other entity types listed in Table 27.

http://www.opengis.net/spec/iot_sensing/1.0/req/multi-datastream/relations

### Table 26 Properties of a MultiDatastream entity

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>A property provides a label for Datastream entity, commonly a descriptive name</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>description</td>
<td>The description of the Datastream entity.</td>
<td>CharacterString</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>
**unitOfMeasurements**

A JSON array of JSON objects that containing three key-value pairs. The name property presents the full name of the unitOfMeasurement; the symbol property shows the textual form of the unit symbol; and the definition contains the URI defining the unitOfMeasurement. (see Req 42 for the constraints between unitOfMeasurement, multiObservationDataType and result)

<table>
<thead>
<tr>
<th>ObservationType</th>
<th>Description</th>
<th>ValueCode and its value SHALL be OM_ComplexObservation.</th>
<th>One (mandatory)</th>
</tr>
</thead>
<tbody>
<tr>
<td>multiObservationDataTypes</td>
<td>This property defines the observationType of each element of the result of a complex Observation.</td>
<td>A JSON array of ValueCode. See Table 12 for the available ValueCodes.</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td>observedArea</td>
<td>The spatial bounding box of the spatial extent of all FeatureOfInterests that belong to the Observations associated with this MultiDatastream.</td>
<td>GM_Envelope (GeoJSON Polygon)</td>
<td>Zero-to-one</td>
</tr>
<tr>
<td>phenomenonTime</td>
<td>The temporal interval of the phenomenon times of all observations belonging to this MultiDatastream.</td>
<td>TM_Period (ISO 8601 Time Interval)</td>
<td>Zero-to-one</td>
</tr>
<tr>
<td>resultTime</td>
<td>The temporal interval of the result times of all observations belonging to this MultiDatastream.</td>
<td>TM_Period (ISO 8601 Time Interval)</td>
<td>Zero-to-one</td>
</tr>
</tbody>
</table>

**Table 27 Direct relation between a MultiDataStream entity and other entity types**

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thing</td>
<td>Many optional to one mandatory</td>
<td>A Thing has zero-to-many MultiDataStream. A MultiDataStream entity SHALL only link to a Thing as a collection of Observations.</td>
</tr>
<tr>
<td>Sensor</td>
<td>Many optional to one mandatory</td>
<td>The Observations in a MultiDataStream are performed by one-and-only-one Sensor. One Sensor MAY produce zero-to-many Observations in different MultiDatastreams.</td>
</tr>
<tr>
<td>ObservedProperty</td>
<td>Many optional to many</td>
<td>The Observations of a MultiDataStream SHALL observe the same ObservedProperties entity set.</td>
</tr>
<tr>
<td>mandatory</td>
<td>A MultiDatastream has zero-to-many Observations. One Observation SHALL occur in one-and-only-one MultiDatastream.</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

**Table 28 Direct relation between an MultiDatastream’s Observation entity and other entity types**

<table>
<thead>
<tr>
<th>Entity type</th>
<th>Relation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MultiDatastream</td>
<td>Many optional to one mandatory</td>
<td>A MultiDatastream can have zero-to-many Observations. One Observation SHALL occur in one-and-only-one MultiDatastream.</td>
</tr>
<tr>
<td>FeatureOfInterest</td>
<td>Many optional to one mandatory</td>
<td>An Observation observes on one-and-only-one FeatureOfInterest. One FeatureOfInterest could be observed by one-to-many Observations.</td>
</tr>
</tbody>
</table>

**Req 42** The size and the order of each element of a MultiDatastream’s unitOfMeasurements array (i.e., MultiDatastream(id)/unitOfMeasurements) SHALL match the size and the order of each element of the related ObservedProperties collection (i.e., MultiDatastreams(id)/ObservedProperties).

The size and the order of each element of a MultiDatastream’s unitOfMeasurements array (i.e., MultiDatastreams(id)/unitOfMeasurements) SHALL match the size and the order of each element of all related Observations’ result (i.e., MultiDatastreams(id)/Observations?$select=result).

The size and the order of each element of a MultiDatastream’s unitOfMeasurements array (i.e., MultiDatastreams(id)/unitOfMeasurements) SHALL match the size and the order of each element of the MultiDatastream’s multiObservationDataTypes array (i.e., MultiDatastreams(id)/multiObservationDataTypes).

When a complex result’s element does not have a unit of measurement (e.g., a OM_TruthObservation type), the corresponding unitOfMeasurement element SHALL have null values.

http://www.opengis.net/spec/iot_sensing/1.0/req-multi-datastream/constraints

**Example 32: MultiDatastream entity example 1**
Example 33: an example ObservedProperties collection of the above MultiDatastream:
Please note that the order of the elements in the value array match the order of the related Observations/result array as well as the order of the related unitOfMeasurements array.
Example 34: an example Observation of the above MultiDatastream: Please note that the order of the elements in the result array match (1) the order of the related ObservedProperties (i.e., Observation(id)/MultiDatastreams(id)/ObservedProperties), (2) the order of the related unitOfMeasurements array (i.e., Observation(id)/MultiDatastream(id)/unitOfMeasurements) and (3) the order of the related multiObservationDataTypes (i.e., Observation(id)/MultiDatastream(id)/multiObservationDataTypes).
13. SensorThings Data Array Extension

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/data-array">http://www.opengis.net/spec/iot_sensing/1.0/req/data-array</a></td>
</tr>
<tr>
<td>Target Type</td>
</tr>
<tr>
<td>Requirement</td>
</tr>
</tbody>
</table>

Req 43 To support the SensorThings data array extension, a service SHALL support the retrieval and creation of observations as defined in Section 13.

http://www.opengis.net/spec/iot_sensing/1.0/req/data-array/data-array

Similar to the SWE DataArray in the OGC SOS, SensorThings API also provides the support of dataArray (in addition to formatting every observation entity as a JSON object) to aggregate multiple Observation entities and reduce the request (e.g., POST) and response (e.g., GET) size. SensorThings mainly use dataArray in two scenarios: (1) get Observation entities in dataArray, and (2) create Observation entities with dataArray.

13.1 Retrieve a Datastream’s Observation entities in dataArray

In SensorThings services, users are able to request for multiple Observation entities and format the entities in the dataArray format. When a SensorThings service returns a dataArray response, the service groups Observation entities by Datastream or MultiDatastream, which means the Observation entities that link to the same Datastream or the same MultiDatastream are aggregated in one dataArray.
13.1.1 Request
In order to request for `dataArray`, users must include the query option "$resultFormat=dataArray" when requesting Observation entities. For example, `http://example.org/v1.0/Observations?$resultFormat=dataArray`.

13.1.2 Response
The response `Observations` in `dataArray` format contains the following properties.

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DataStream</strong> or <strong>MultiDataStream</strong></td>
<td>The navigationLink of the Datastream or the MultiDatastream entity used to group Observation entities in the <code>dataArray</code>.</td>
<td>navigationLink</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><strong>components</strong></td>
<td>An ordered array of Observation property names whose matched values are included in the <code>dataArray</code>.</td>
<td>An ordered array of Observation property names</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><strong>dataArray</strong></td>
<td>A JSON Array containing Observation entities. Each Observation entity is represented by the ordered property values, which match with the ordered property names in <code>components</code>.</td>
<td>JSON Array</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

Example 35: an example of getting Observation entities from a Datastream in `dataArray` result format:
GET /v1.0/Datastreams(1)/Observations?$resultFormat=dataArray

HTTP/1.1 200 OK
Host: www.example.org/
Content-Type: application/json

{
"value": [
{
"Datastream@iot.navigationLink": "Datastreams(1)",
"components": [
"id",
"phenomenonTime",
"resultTime",
"result"
],
"dataArray@iot.count":3,
"dataArray": [
[
1,
"2005-08-05T12:21:13Z",
"2005-08-05T12:21:13Z",
20
],
[
2,
"2005-08-05T12:22:08Z",
"2005-08-05T12:21:13Z",
30
],
[
3,
"2005-08-05T12:22:54Z",
"2005-08-05T12:21:13Z",
0
]
]
}
}

Example 36: an example of getting Observation entities from a MultiDatastream in dataArray result format
13.2 Create Observation entities with dataArray

Besides creating observation entities one by one with multiple HTTP POST requests, there is a need to create multiple Observation entities with a lighter message body in a single HTTP request. In this case, a sensing system can buffer multiple Observations and send them to a SensorThings service in one HTTP request. Here we propose an Action operation CreateObservations.
13.2.1 Request

Users can invoke the `CreateObservations` action by sending a HTTP `POST` request to the `SERVICE_ROOT_URL/CreateObservations`.

For example, http://example.org/v1.0/CreateObservations.

The message body aggregates `Observations` by `Datastreams`, which means all the `Observations` linked to one `Datastream` SHALL be aggregated in one JSON object. The parameters of each JSON object are shown in the following table.

As an `Observation` links to one `FeatureOfInterest`, to establish the link between an `Observation` and a `FeatureOfInterest`, users should include the `FeatureOfInterest` ids in the `dataArray`. If no `FeatureOfInterest` id is presented, the `FeatureOfInterest` will be created based on the `Location` entities of the linked `Thing` entity by default.

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data type</th>
<th>Multiplicity and use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DataStream</strong></td>
<td>The unique identifier of the <code>Datastream</code> linking to the group of <code>Observation</code> entities in the <code>dataArray</code>.</td>
<td>The unique identifier of a <code>Datastream</code></td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><strong>components</strong></td>
<td>An ordered array of <code>Observation</code> property names whose matched values are included in the <code>dataArray</code>. At least the <code>phenomenonTime</code> and <code>result</code> properties SHALL be included. To establish the link between an <code>Observation</code> and a <code>FeatureOfInterest</code>, the component name is &quot; FeatureOfInterest/id&quot; and the <code>FeatureOfInterest</code> ids should be included in the <code>dataArray</code> array. If no <code>FeatureOfInterest</code> id is presented, the <code>FeatureOfInterest</code> will be created based on the <code>Location</code> entities of the linked <code>Thing</code> entity by default.</td>
<td>An ordered array of <code>Observation</code> property names</td>
<td>One (mandatory)</td>
</tr>
<tr>
<td><strong>dataArray</strong></td>
<td>A JSON Array containing <code>Observations</code>. Each <code>Observation</code> is represented by the ordered property values. The ordered property values match with the ordered property names in <code>components</code>.</td>
<td>JSON Array</td>
<td>One (mandatory)</td>
</tr>
</tbody>
</table>

Example 37: example of a request for creating `Observation` entities in `dataArray`
POST /v1.0/CreateObservations HTTP/1.1
Host: example.org/
Content-Type: application/json

[ { "Datastream": { "@iot.id": 1 }, "components": [ "phenomenonTime", "result", "FeatureOfInterest/id" ], "dataArray@iot.count":2, "dataArray": [ [ "2010-12-23T10:20:00-0700", 20, 1 ] ] }, { "Datastream": { "@iot.id": 2 }, "components": [ "phenomenonTime", "result", "FeatureOfInterest/id" ], "dataArray@iot.count":2, "dataArray": [ [ "2010-12-23T10:20:00-0700", 65, 1 ] ], [ "2010-12-23T10:21:00-0700", 60, 1 ] ] } ]

13.2.2 Response

Upon successful completion the service SHALL respond with 201 Created. The response message body SHALL contain the URLs of the created Observation entities, where the order of URLs must match with the order of Observations in the dataArray from the request. In the case of the service having exceptions when creating individual observation
entities, instead of responding with URLs, the service must specify "error" in the corresponding array element.

Example 38: an example of a response of creating Observation entities with dataArray

```plaintext
POST /v1.0/CreateObservations HTTP/1.1
201 Created
Host: example.org
Content-Type: application/json

[
  "http://examples.org/v1.0/Observations(1)",
  "error",
  "http://examples.org/v1.0/Observations(2)"
]
```

14. SensorThings Sensing MQTT Extension

In addition to support HTTP protocol, a SensorThings service MAY support MQTT protocol to enhance the SensorThings service publish and subscribe capabilities. This section describes the SensorThings MQTT extension.

14.1 Create a SensorThings Observation with MQTT Publish

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt">http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Type</th>
<th>Web Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement</td>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt/observations-creation">http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt/observations-creation</a></td>
</tr>
<tr>
<td>Dependency</td>
<td><a href="http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html">http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html</a></td>
</tr>
</tbody>
</table>

Req 44 To allow clients to create observations with MQTT Publish, a service SHALL support the creation of observations with MQTT as defined in Section 14.1.

http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt/observations-creation

SensorThings MQTT extension provides the capability of creating Observation entity using MQTT protocol. To create an Observation entity in MQTT, the client sends a MQTT Publish request to the SensorThings service and the MQTT topic is the Observations resource path. The MQTT application message contains a single valid Observation entity
representation. Figure 4 contains the sequence diagram for creating Observation using MQTT publish as well as MQTT sending notifications for Observation creation.

![Sequence Diagram](image)

**Figure 4 Creating Observations using MQTT publish, and receive notifications for Observations with MQTT**

If the MQTT topic for the Observation is a `navigationLink` from Datastream or FeatureOfInterest, the new Observation entity is automatically linked to that Datastream or FeatureOfInterest respectively.

Similar to creating Observations with `HTTP POST`, creating Observations with `MQTT Publish` follow the integrity constraints for creating Observation listed in **Reference source not found.** The two special cases defined in Req 33 are also applied in the case of creating Observations with `MQTT Publish`.

**14.1.1 Link to existing entities when creating an Observation entity**
To link to existing entities when creating an Observation entity with MQTT, the conditions in Req 34 is applied.

**14.1.2 Create related entities when creating an Observation entity (deep insert)**
To create related entities when creating an entity with MQTT, the condition in Req 35 is applied.
### 14.2 Receive updates with MQTT Subscribe

<table>
<thead>
<tr>
<th>Requirements Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.opengis.net/spec/iot_sensing/1.0/req/receive-updates-via-mqtt">http://www.opengis.net/spec/iot_sensing/1.0/req/receive-updates-via-mqtt</a></td>
</tr>
<tr>
<td><strong>Target Type</strong></td>
</tr>
<tr>
<td><strong>Requirement</strong></td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
</tr>
</tbody>
</table>

**Req 45** To allow clients to receive notifications for the updates of SensorThings entities with MQTT, a service SHALL support the receiving updates with MQTT Subscribe as defined in Section 14.2.

http://www.opengis.net/spec/iot_sensing/1.0/req/receive-updates-via-mqtt/receive-updates

To receive notifications from a SensorThings service when some entities updated, a client can send a MQTT Subscribe request to the SensorThings service. SensorThings API defined the following four MQTT subscription use cases. Figure 5 contains the sequence diagram of receiving updates using MQTT Subscribe.

![Figure 5 Sequence diagram for receiving updates using MQTT subscribe](image-url)
14.2.1 Receive updates of a SensorThings entity set with MQTT Subscribe
MQTT Control Packet: Subscribe

**Topic Pattern:** RESOURCE_PATH/COLLECTION_NAME

**Example Topic:** Datastreams(1)/Observations

**Response:** When a new entity is added to the entity set (e.g., a new Observation created) or an existing entity of the entity set is updated, the service returns a complete JSON representation of the newly created or updated entity.

14.2.2 Receive updates of a SensorThings entity with MQTT Subscribe
MQTT Control Packet: Subscribe

**Topic Pattern:** RESOURCE_PATH_TO_AN_ENTITY

**Example Topic:** Datastreams(1)

**Response:** When a property of the subscribed entity is updated, the service returns a complete JSON representation of the updated entity.

14.2.3 Receive updates of a SensorThings entity’s property with MQTT Subscribe
MQTT Control Packet: Subscribe

**Topic Pattern:** RESOURCE_PATH_TO_AN_ENTITY/PROPERTY_NAME

**Example Topic:** Datastreams(1)/observedArea

**Response:** When the value of the subscribed property is changed, the service returns a JSON object. The returned JSON object follows as defined in Section 9.2.4 - Usage 4: address to a property of an entity.

**Example 39:** an example response of receiving updates of an entity’s property with MQTT Subscribe.

The example shows a sample response of the following MQTT topic subscription – Datastreams(1)/description

```json
{
  "description": "This is an updated description of a thing"
}
```

14.2.4 Receive updates of the selected properties of the newly created entities or updated entities of a SensorThings entity set with MQTT Subscribe

MQTT Control Packet: Subscribe

**Topic Pattern:** RESOURCE_PATH/COLLECTION_NAME?$select=PROPERTY_1,PROPERTY_2,...
Response: When a new entity is added to an entity set or an existing entity is updated (e.g., a new Observation created or an existing Observation is updated), the service returns a JSON representation of the selected properties of the newly created or updated entity.

Note: In the case of an entity’s property is updated, it is possible that the selected properties are not the updated property, so that the returned JSON does not reflect the update.

Example 40: an example response of receiving updates of the selected property of an entity set with MQTT Subscribe. - The example shows a sample response of the following MQTT topic subscription -

Datastreams(1)/Observations?$select=phenomenonTime,result

```json
{
    "result": 45,
    "phenomenonTime": "2015-02-05T17:00:00Z"
}
```
Annex A: Conformance Class Abstract Test Suite (Normative)

A.1 SensorThings Read (Core) Tests

This section contains the conformance classes for the SensorThings API Read (Core). The SensorThings API service needs to pass all the conformance tests defined in this section.

A.1.1 Conformance class: SensorThings API Entity Control Information

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information/common-control-information

Test: Common Control Information

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information/common-control-information</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>1. <a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information">http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if each entity has the common control information as defined in the requirement <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information">http://www.opengis.net/spec/iot_sensing/1.0/req/entity-control-information/common-control-information</a>.</td>
</tr>
<tr>
<td>Test method</td>
<td>Inspect the full JSON object of the entity sets (i.e., without $select) to identify, if each entity has the common control information defined in the above requirement and the service sends appropriate responses as defined in this specification.</td>
</tr>
</tbody>
</table>

A.1.2 Conformance class: SensorThings API Thing Entity

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/thing

Test: Thing Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/thing/thing-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/thing/thing-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 2. http://www.opengis.net/spec/iot_sensing/1.0/req/thing/properties  
| | 3. http://www.opengis.net/spec/iot_sensing/1.0/req/thing/relations |
| Test purpose | Check if each Thing entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Thing entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
| | Inspect the full JSON object of each Thing entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., |
A.1.3 Conformance class: SensorThings API Location Entity

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/location

Test: Location Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/location/location-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/location/location-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 4. http://www.opengis.net/spec/iot_sensing/1.0/req/location/properties  
                  5. http://www.opengis.net/spec/iot_sensing/1.0/req/location/relations |
| Test purpose | Check if each Location entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Location entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
                     Inspect the full JSON object of each Location entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement. |

A.1.4 Conformance class: SensorThings API HistoricalLocation Entity

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location

Test: Historicallocation Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location/historical-location-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location/historical-location-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 6. http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/properties  
                  7. http://www.opengis.net/spec/iot_sensing/1.0/req/historical-location/relations |
| Test purpose | Check if each Historicallocation entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Historicallocation entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
                     Inspect the full JSON object of each Historicallocation entity set (i.e., without using $select) to identify, if each entity has the mandatory relations defined in the corresponding requirement. |
the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement.

A.1.5 Conformance class: SensorThings API Datastream Entity

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream

Test: Datastream Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream/datastream-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream/datastream-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 9. http://www.opengis.net/spec/iot_sensing/1.0/req/datastream/properties  
10. http://www.opengis.net/spec/iot_sensing/1.0/req/datastream/relations |
| Test purpose | Check if each Datastream entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Datastream entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
Inspect the full JSON object of each Datastream entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement. |

A.1.6 Conformance class: SensorThings API Sensor Entity

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor

Test: Sensor Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor/sensor-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor/sensor-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 11. http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/properties  
12. http://www.opengis.net/spec/iot_sensing/1.0/req/sensor/relations |
| Test purpose | Check if each Sensor entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Sensor entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
Inspect the full JSON object of each Sensor entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement. |
query option) to identify, if each entity has the mandatory relations \( (i.e., \ @iot.navigationLink) \) defined in the corresponding requirement.

### A.1.7 Conformance class: SensorThings API ObservedProperty Entity

**Conformance class id:** http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property

**Test:** ObservedProperty Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property/observed-property-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property/observed-property-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 13. http://www.opengis.net/spec/iot_sensing/1.0/req/observed-property/properties  
14. http://www.opengis.net/spec/iot_sensing/1.0/req/observed-property/relations |
| Test purpose | Check if each ObservedProperty entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the ObservedProperty entity sets \( (i.e., \text{without} \ \$select) \) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
Inspect the full JSON object of each ObservedProperty entity set \( (i.e., \text{without using the} \ \$select \ \text{query option}) \) to identify, if each entity has the mandatory relations \( (i.e., \ @iot.navigationLink) \) defined in the corresponding requirement. |

### A.1.8 Conformance class: SensorThings API Observation Entity

**Conformance class id:** http://www.opengis.net/spec/iot_sensing/1.0/conf/observation

**Test:** Observation Entity

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/observation/observation-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/observation/observation-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 15. http://www.opengis.net/spec/iot_sensing/1.0/req/observation/properties  
16. http://www.opengis.net/spec/iot_sensing/1.0/req/observation/relations |
| Test purpose | Check if each Observation entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the Observation entity sets \( (i.e., \text{without} \ \$select) \) to identify, if each entity has the mandatory properties defined in the corresponding requirement. |
Inspect the full JSON object of each Observation entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement.

### A.1.9 Conformance class: SensorThings API FeatureOfInterest Entity

**Conformance class id:** [http://www.opengis.net/spec/iot_sensing/1.0/conf/feature-of-interest](http://www.opengis.net/spec/iot_sensing/1.0/conf/feature-of-interest)

**Test: FeatureOfInterest Entity**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/feature-of-interest/feature-of-interest-valid">http://www.opengis.net/spec/iot_sensing/1.0/conf/feature-of-interest/feature-of-interest-valid</a></th>
</tr>
</thead>
</table>
| Requirements | 17. [http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/properties](http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/properties)  
18. [http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/relations](http://www.opengis.net/spec/iot_sensing/1.0/req/feature-of-interest/relations) |
| Test purpose | Check if each FeatureOfInterest entity has the mandatory properties and mandatory relations as defined in this specification. |
| Test method | Inspect the full JSON object of the FeatureOfInterest entity sets (i.e., without $select) to identify, if each entity has the mandatory properties defined in the corresponding requirement.  
Inspect the full JSON object of each FeatureOfInterest entity set (i.e., without using the $select query option) to identify, if each entity has the mandatory relations (i.e., @iot.navigationLink) defined in the corresponding requirement. |

### A.1.10 Conformance class: SensorThings API Resource Path

**Conformance class id:** [http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path](http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path)

**Test: Resource Path**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path/resource-path-to-entities">http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path/resource-path-to-entities</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>19. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path/resource-path-to-entities">http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path/resource-path-to-entities</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the service supports all the resource path usages as defined in the requirement <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path/resource-path-to-entities">http://www.opengis.net/spec/iot_sensing/1.0/req/resource-path/resource-path-to-entities</a>.</td>
</tr>
<tr>
<td>Test method</td>
<td>Inspect the service to identify, if each resource path usage has been implemented property.</td>
</tr>
</tbody>
</table>
A.2 SensorThings API Filtering Extension Tests

This section contains the conformance classes for the SensorThings API filtering extension. That means a SensorThings API service that allows clients to further filter data with query options needs to pass the conformance tests defined in this section.

A.2.1 Conformance class: SensorThings API Request Data with Filters

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data

Dependencies:

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path

A.2.1.1 Test: Query Option Order

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/order">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/order</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>22. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/order">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/order</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the results of the service requests are as if the system query options were evaluated in the order as defined in this specification.</td>
</tr>
<tr>
<td>Test method</td>
<td>Send a query includes the query options listed in requirement <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/order">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/order</a>, and check if the results are evaluated according to the order defined in this specification.</td>
</tr>
</tbody>
</table>

A.2.1.2 Test: Request Data with $expand and $select

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/expand-and-select">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/expand-and-select</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>23. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/expand">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/expand</a></td>
</tr>
<tr>
<td></td>
<td>24. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/select">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/select</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the service supports $expand and $select as defined in this specification.</td>
</tr>
<tr>
<td>Test method</td>
<td>Send requests with $expand following the different usages as defined in the requirement <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/expand">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/expand</a>, check if the server returns appropriate result as defined in this specification. Send requests with the $select option following the different usages as defined in the requirement <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/select">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/select</a>, check if the server returns appropriate result as defined in this specification.</td>
</tr>
</tbody>
</table>

**A.2.1.3 Test: Query Option Response Code**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/status-codes">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/status-codes</a></th>
</tr>
</thead>
</table>
| Requirements | 20. http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/status-code  
| Test purpose | Check when a client requests an entity that is not available in the service, if the service responds with 404 Not Found or 410 Gone as defined in the requirement http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/status-code. Check when a client use a query option that doesn't support by the service, if the service fails the request and responds with 501 NOT Implemented as defined in the requirement http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/query-status-code. |
| Test method | Send a HTTP request for an entity that is not available in the service, check if the server returns 404 Not Found or 410 Gone. (If applicable) Send a query with a query option that is not supported by the service, check if the server returns 501 Not Implemented. |

**A.2.1.4 Test: Sorting Query Option**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/sorting">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/sorting</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>25. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/orderby">http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/orderby</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the service supports the $orderby query option as defined in this specification.</td>
</tr>
<tr>
<td>Test method</td>
<td>Send a query with the $orderby query option, check if the server returns appropriate result as defined in this specification.</td>
</tr>
</tbody>
</table>

**A.2.1.5 Test: Client-driven Pagination Query Option**
<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/client-driven-pagination">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/client-driven-pagination</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Test purpose</td>
<td>Check if the service supports the <code>$top</code>, <code>$skip</code> and <code>$count</code> query option as defined in this specification.</td>
</tr>
</tbody>
</table>
| Test method | Send a query with the `$top` query option, check if the server returns appropriate result as defined in this specification.  
Send a query with the `$skip` query option, check if the server returns appropriate result as defined in this specification.  
Send a query with the `$count` query option, check if the server returns appropriate result as defined in this specification. |

**A.2.1.6 Test: Filter Query Option**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/filter-query-options">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/filter-query-options</a></th>
</tr>
</thead>
</table>
| Requirements | 29. http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/filter  
| Test purpose | Check if the service supports the `$filter` query option and the built-in filter operators and built-in filter functions as defined in this specification. |
| Test method | Send a query with the `$filter` query option, check if the server returns appropriate result as defined in this specification.  
Send a query with the `$filter` query option for each built-in filter operator, check if the server returns appropriate result as defined in this specification.  
Send a query with the `$filter` query option for each built-in filter function, check if the server returns appropriate result as defined in this specification. |

**A.2.1.7 Test: Server-driven Pagination**

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/server-driven-pagination">http://www.opengis.net/spec/iot_sensing/1.0/conf/request-data/server-driven-pagination</a></th>
</tr>
</thead>
</table>

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Test purpose
Check if the service supports the server-driven pagination as defined in the requirement
http://www.opengis.net/spec/iot_sensing/1.0/req/request-data/pagination.

Test method
Send a query to list all entities of an entity set, check if the server returns a subset of the
requested entities as defined in this specification.

### A.3 SensorThings API Create-Update-Delete Extension Tests

This section contains the conformance classes for the SensorThings API create-update-delete
extension. That means a SensorThings API service that allows clients to create/update/delete
entities needs to pass the conformance tests defined in this section.

#### A.3.1 Conformance class: SensorThings API Create-Update-Delete

**Conformance class id:** http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete

**Dependencies:**

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path

#### A.3.1.1 Test: Sensing Entity Creation

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete/sensing-entity-creation">http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete/sensing-entity-creation</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>33. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/create-entity">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/create-entity</a></td>
</tr>
<tr>
<td></td>
<td>34. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/link-to-existing-entities">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/link-to-existing-entities</a></td>
</tr>
<tr>
<td></td>
<td>35. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert</a></td>
</tr>
<tr>
<td></td>
<td>36. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert-status-code">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/deep-insert-status-code</a></td>
</tr>
<tr>
<td></td>
<td>8. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/historical-location-</a></td>
</tr>
<tr>
<td>auto-creation</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td><strong>Test purpose</strong></td>
<td>Check if the service supports the creation of entities as defined in this specification.</td>
</tr>
<tr>
<td><strong>Test method</strong></td>
<td>For each SensorThings entity type creates an entity instance by following the integrity constraints of Table 24 and creating the related entities with a single request (<em>i.e.</em>, deep insert), check if the entity instance is successfully created and the server responds as defined in this specification.</td>
</tr>
<tr>
<td></td>
<td>Create an entity instance and its related entities with a deep insert request that does not conform to the specification (<em>e.g.</em>, missing a mandatory property), check if the service fails the request without creating any entity within the deep insert request and responds the appropriate HTTP status code.</td>
</tr>
<tr>
<td></td>
<td>For each SensorThings entity type issue an entity creation request that does not follow the integrity constraints of Table 24 with deep insert, check if the service fails the request without creating any entity within the deep insert request and responds the appropriate HTTP status code.</td>
</tr>
<tr>
<td></td>
<td>For each SensorThings entity type creates an entity instance by linking to existing entities with a single request, check if the server responds as defined in this specification.</td>
</tr>
<tr>
<td></td>
<td>For each SensorThings entity type creates an entity instance that does not follow the integrity constraints of Table 24 by linking to existing entities with a single request, check if the server responds as defined in this specification.</td>
</tr>
<tr>
<td></td>
<td>Create an Observation entity for a Datastream without any Observations and the Observation creation request does not create a new or linking to an existing FeatureOfInterest, check if the service creates a new FeatureOfInterest for the created Observation with the location property of the Thing’s Location entity.</td>
</tr>
<tr>
<td></td>
<td>Create an Observation entity for a Datastream that already has Observations and the Observation creation request does not create a new or linking to an existing FeatureOfInterest, check if the service automatically links the newly created Observation with an existing FeatureOfInterest whose location property is from the Thing’s Location entity.</td>
</tr>
<tr>
<td></td>
<td>Create an Observation entity and the Observation creation request does not include resultTime, check if the resultTime property is created with a null value.</td>
</tr>
<tr>
<td></td>
<td>Create a Location for a Thing entity, check if the Thing has a HistoricalLocation created by the service according to the Location entity.</td>
</tr>
</tbody>
</table>

**A.3.1.2 Test: Sensing Entity Update**

| Test id | http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete/update-entity |
### A.3.1.3 Test: Sensing Entity Deletion

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete/sensing-entity-deletion">http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete/sensing-entity-deletion</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>38. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/delete-entity">http://www.opengis.net/spec/iot_sensing/1.0/req/create-update-delete/delete-entity</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the service supports the deletion of entities as defined in Section 10.4.</td>
</tr>
<tr>
<td>Test method</td>
<td>Delete an entity instance, and check if the service responds as defined in Section 10.4.</td>
</tr>
</tbody>
</table>

### A.4 SensorThings API Batch Request Extension Tests

This section contains the conformance classes for the SensorThings API batch request extension. That means a SensorThings API service that allows clients to send a single HTTP request that groups multiple requests needs to pass the conformance tests defined in this section.

#### A.4.1 Conformance class: SensorThings API Batch Request

**Conformance class id:** http://www.opengis.net/spec/iot_sensing/1.0/conf/batch-request

**Dependencies:**

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
A.4.1.1 Test: Batch Request

<table>
<thead>
<tr>
<th>Test id</th>
<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/batch-request/batch-request">http://www.opengis.net/spec/iot_sensing/1.0/conf/batch-request/batch-request</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>39. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request/batch-request">http://www.opengis.net/spec/iot_sensing/1.0/req/batch-request/batch-request</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if the service supports the batch request as defined in Section 11.</td>
</tr>
<tr>
<td>Test method</td>
<td>Submit batch requests according to the examples listed in Section 11, check if the service responds as defined in this specification.</td>
</tr>
</tbody>
</table>

A.5 SensorThings API MultipleDatastream Tests

This section contains the conformance classes for the SensorThings API MultiDatastream extension. That means a SensorThings API service that allows clients to group a collection of observations’ results into an array (i.e., a complex result type) needs to pass the conformance tests defined in this section.

A.5.1 Conformance class: SensorThings API MultiDatastream

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/multi-datastream

Dependencies:

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path

A.5.1.1 Test: SensorThings API MultiDatastream
A.6 SensorThings API Data Array Extension

This section contains the conformance classe for the SensorThings API data array extension. That means a SensorThings API service that allows clients to request the compact data array encoding defined in this specification needs to pass the conformance tests defined in this section.

A.6.1 Conformance class: SensorThings API Data Array

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/data-array

Dependencies:

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path

A.6.1.1 Test: SensorThings API Sensing Data Array

| Test id | http://www.opengis.net/spec/iot_sensing/1.0/conf/data-array/data-array-valid |
|------------------------------------------|
| Requirements | 43. http://www.opengis.net/spec/iot_sensing/1.0/req/data-array/data-array |
| Test purpose | Check if the service supports the data array extension as defined in Section 13. |
Test method: Issue a GET request for Datastreams (and MultiDatastreams if applicable) that includes the query option "$resultFormat=dataArray", and then inspect the returned JSON to identify if it fulfills the data array format as defined in Section 13.

Create at least two Datastreams by using the data array format as defined in Section 13. Inspect the response code and returned JSON to identify if it fulfills the response as defined in Section 13.

A.7 SensorThings API Observation Creation via MQTT Extension Tests

This section contains the conformance class for the SensorThings API Observation creation extension. That means a SensorThings API service that allows clients to create Observations via MQTT needs to pass the conformance tests defined in this section.

A.7.1 Conformance class: SensorThings API Observation Creation via MQTT

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/create-observations-via-mqtt

Dependencies:

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path
11. http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete

A.7.1.1 Test: SensorThings API Observation Creation via MQTT

<table>
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<th><a href="http://www.opengis.net/spec/iot_sensing/1.0/conf/create-observations-via-mqtt/observation-creation">http://www.opengis.net/spec/iot_sensing/1.0/conf/create-observations-via-mqtt/observation-creation</a></th>
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<td>Requirements</td>
<td>44, <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt/observation-creation">http://www.opengis.net/spec/iot_sensing/1.0/req/create-observations-via-mqtt/observation-creation</a></td>
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<tr>
<td>Test purpose</td>
<td>Check if the service supports the creation and update of entities via MQTT as defined in Section 14.1.</td>
</tr>
<tr>
<td>Test method</td>
<td>Create an Observation entity instance containing binding information for navigation</td>
</tr>
</tbody>
</table>
properties using MQTT Publish, check if the server responds as defined in Section 14.1.

A.8  SensorThings API Receiving Updates via MQTT Extension Tests

This section contains the conformance class for the SensorThings API receiving updates extension. That means a SensorThings API service that allows clients to receive notifications regarding updates of entities via MQTT needs to pass the conformance tests defined in this section.

A.8.1  Conformance class: SensorThings API Receiving Updates via MQTT

Conformance class id: http://www.opengis.net/spec/iot_sensing/1.0/conf/receive-updates-via-mqtt

Dependencies:

1. http://www.opengis.net/spec/iot_sensing/1.0/conf/entity-control-information
2. http://www.opengis.net/spec/iot_sensing/1.0/conf/thing
3. http://www.opengis.net/spec/iot_sensing/1.0/conf/location
4. http://www.opengis.net/spec/iot_sensing/1.0/conf/historical-location
5. http://www.opengis.net/spec/iot_sensing/1.0/conf/datastream
6. http://www.opengis.net/spec/iot_sensing/1.0/conf/sensor
7. http://www.opengis.net/spec/iot_sensing/1.0/conf/observed-property
8. http://www.opengis.net/spec/iot_sensing/1.0/conf/observation
10. http://www.opengis.net/spec/iot_sensing/1.0/conf/resource-path
11. http://www.opengis.net/spec/iot_sensing/1.0/conf/create-update-delete

A.8.1.1 Test: SensorThings API Receiving Updates via MQTT

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<td>Requirements</td>
<td>45. <a href="http://www.opengis.net/spec/iot_sensing/1.0/req/receive-updates-via-mqtt/receive-updates">http://www.opengis.net/spec/iot_sensing/1.0/req/receive-updates-via-mqtt/receive-updates</a></td>
</tr>
<tr>
<td>Test purpose</td>
<td>Check if a client can receive notifications for the updates of a SensorThings entity set or an individual entity with MQTT.</td>
</tr>
</tbody>
</table>
| Test method | Subscribe to an entity set with MQTT Subscribe. Then create a new entity of the subscribed entity set. Check if a complete JSON representation of the newly created entity through MQTT is received.  

Subscribe to an entity set with MQTT Subscribe. Then update an existing entity of the subscribed entity set. Check if a complete JSON representation of the updated entity through MQTT is received. |
Subscribe to an entity’s property with MQTT Subscribe. Then update the property with PATCH. Check if the JSON object of the updated property is received.

Subscribe to multiple properties of an entity set with MQTT Subscribe. Then create a new entity of the entity set. Check if a JSON object of the subscribed properties is received.

Subscribe to multiple properties of an entity set with MQTT Subscribe. Then update an existing entity of the entity set with PATCH. Check if a JSON object of the subscribed properties is received.
Annex B: Revision history

<table>
<thead>
<tr>
<th>Date</th>
<th>Release</th>
<th>Author</th>
<th>Paragraph modified</th>
<th>Description</th>
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<tr>
<td>2015-01-24</td>
<td>0.9.0</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the Calgary and Tokyo TC SWG meeting. Changed trajectory to HistoricalLocation.</td>
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<tr>
<td>2015-02-24</td>
<td>0.9</td>
<td>Carl Reed</td>
<td>Many.</td>
<td>Major edit and alignment with OGC document template.</td>
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<td>2015-04-11</td>
<td>0.9</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the Barcelona TC SWG meeting. Changed ComplexDatastream to MultiDatastream.</td>
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<td>2015-05-11</td>
<td>0.9.1</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the OGC Architecture Board meeting on May 5\textsuperscript{th} 2015. Added requirement classes.</td>
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<tr>
<td>2015-06-11</td>
<td>0.9.2</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the OGC Architecture Board meeting on May 19\textsuperscript{th} 2015. Revised requirement classes to follow the OGC Naming Authority. Changed common properties to common control information. Added support to server-side pagination for expanded related entities.</td>
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<tr>
<td>2015-08-24</td>
<td>0.9.3</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the RFC comments. Added requirement classes. Added dependencies. Added a section to describe the relationship between this specification and O&amp;M as well as OData.</td>
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<tr>
<td>2015-10-26</td>
<td>1.0</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to the OGC Architecture Board meeting on October 12\textsuperscript{th} 2015. Updated a section to explain the design decision of choosing the OData KVP encoding rather than OGC KVP encoding.</td>
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<td>Version</td>
<td>Author</td>
<td>Contributors</td>
<td>Notes</td>
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<td>1.0</td>
<td>Steve Liang</td>
<td>Many.</td>
<td>Updated according to comments received from the OGC TC approval vote and Washington DC TC SWG meeting.</td>
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<tr>
<td>2016-06-30</td>
<td>1.0</td>
<td>Scott Simmons</td>
<td>All</td>
<td>Editing for final publication</td>
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Annex C: Bibliography


