OGC Web Feature Service 3.0

Part 1 - Core

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OGC Web Feature Service 3.0 - Part 1: Core

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i. Abstract

A Web Feature Service (WFS) offers the capability to create, modify and query spatial data on the Web. WFS is a multi-part standard. This part specifies the core capabilities that every WFS supports and is restricted to read-access to data. Additional capabilities that address specific needs will be specified in additional parts. Examples include support for creating and modifying data, more complex data models, richer queries, additional coordinate reference systems.

By default, every WFS provides access to a single dataset. Rather than sharing the data as a complete dataset, WFS offers direct, fine-grained access to the data at the feature (object) level.

Consistent with the architecture of the Web, this version of WFS uses a resource architecture and specifies a RESTful service interface consistent with the HTTP/HTTPS standards.

This standard specifies discovery and query operations that are implemented using the HTTP GET method. Support for additional methods (in particular POST, PUT, DELETE, PATCH) will be specified in additional parts.

Discovery operations allow the server to be interrogated to determine its capabilities and retrieve information (metadata) about this distribution of the dataset. This includes the API definition of the server as well as metadata about the feature collections provided by the server.

Query operations allow features or values of feature properties to be retrieved from the underlying data store based upon selection criteria, defined by the client, on feature properties.

This standard defines the resources listed in Table 1. For an overview of the resources, see section 7.1 Overview.

Table 1. Overview of resources, applicable HTTP methods and links to the document sections

Resource	Path	HTTP method	Document reference
Landing page	`/`	GET	7.2 API landing page
API definition	`/api`	GET	7.3 API definition
Conformance classes	`/conformance`	GET	7.4 Declaration of conformance classes
Feature collections metadata	`/collections`	GET	7.11 Feature collections metadata
Feature collection metadata	`/collections/{name}`	GET	7.12 Feature collection metadata
Feature collection	`/collections/{name}/items`	GET	7.13 Feature collections
Feature	`/collections/{name}/items/{fid}`	GET	7.14 Feature

ii. Keywords

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, web feature service, wfs, feature, property, geographic information, spatial

data, spatial things, dataset, distribution, API, openapi, geojson, gml, html

iii. Preface

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- CubeWerx Inc.
- interactive instruments GmbH
- …

v. Submitters

All questions regarding this submission should be directed to the editor or the submitters:

Name	Affiliation
Clemens Portele	interactive instruments GmbH

Name	Affiliation
Panagiotis (Peter) A. Vretanos	CubeWerx Inc.
…	…

Chapter 1. Scope

This International Standard specifies the behaviour of a server that provides access to features in a dataset in a manner independent of the underlying data store. It specifies discovery and query operations.

Discovery operations allow the server to be interrogated to determine its capabilities and retrieve information (metadata) about this distribution of the dataset. This includes the API definition of the server as well as metadata about the feature collections provided by the server.

Query operations allow features to be retrieved from the underlying data store based upon simple selection criteria, defined by the client.

Chapter 2. Conformance

This standard defines six requirements / conformance classes.

The standardization targets of all conformance classes are "web services".

The main requirements class is:

- Core.

It specifies requirements that all WFS have to meet.

The "Core" does not mandate any encoding or format for representing features or feature collections. Four requirements classes depend on the "Core" and specify representations for these resources in commonly used encodings for spatial data on the web:

- HTML,
- GeoJSON,
- Geography Markup Language (GML), Simple Features Profile, Level 0, and
- Geography Markup Language (GML), Simple Features Profile, Level 2.

None of these encodings are mandatory and an implementation of the "Core" requirements class may also decide to use none of them, but to use another encoding instead.

That said, the Core requirements class includes recommendations to support HTML and GeoJSON as encodings, where practical. Clause 6 (Overview) includes a discussion about recommended encodings.

The "Core" does not mandate any encoding or format for the formal definition of the API either. One option is the OpenAPI 3.0 specification and a requirements class has been defined for this, which depends on the "Core":

- OpenAPI specification 3.0.

Like with the feature encodings, an implementation of the "Core" requirements class may also decide to use other representations of the API definition in addition or instead of an OpenAPI 3.0 definition. Examples for alternative API definitions: OpenAPI 2.0 (Swagger), future versions of the OpenAPI specification or an OWS Common 2.0 capabilities document.

The "Core" is intended to be the minimal useful service interface for fine-grained access to a spatial dataset.

Additional capabilities, for example, support for transactions, complex data structures, rich queries, other coordinate reference systems, subscription/notification, returning aggregated results, etc., may be specified in future parts of WFS or as vendor-specific extensions.

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.

Chapter 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.

- Open API Initiative: OpenAPI Specification 3.0.1, https://github.com/OAI/OpenAPI-Specification/blob/master/versions/3.0.1.md
- Fielding, R., Gettys, J., Mogul, J., Frystyk, H., Masinter, L., Leach, P., Berners-Lee, T.: IETF RFC 2616, HTTP/1.1, http://tools.ietf.org/rfc/rfc2616.txt
- Nottingham, M.: IETF RFC 5988, Web Linking, http://tools.ietf.org/rfc/rfc5988.txt
- van den Brink, L., Portele, C., Vretanos, P.: OGC 10-100r3, Geography Markup Language (GML) Simple Features Profile, http://portal.opengeospatial.org/files/?artifact_id=42729
- Butler, H., Daly, M., Doyle, A., Gillies, S., Hagen, S., Schaub, T.: IETF RFC 7946, The GeoJSON Format, https://tools.ietf.org/rfc/rfc7946.txt
- W3C: HTML5, W3C Recommendation, http://www.w3.org/TR/html5/
- Schema.org: http://schema.org/docs/schemas.html

Chapter 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.

NOTE	TODO Add link to the informative WFS Guide, once it is available.

4.1. dataset

collection of data, published or curated by a single agent, and available for access or download in one or more formats [DCAT]

4.2. distribution

represents an accessible form of a **dataset** [DCAT]

EXAMPLE: a downloadable file, an RSS feed or a web service that provides the data.

4.3. feature

abstraction of real world phenomena [ISO 19101-1:2014]

NOTE	If you are unfamiliar with the term 'feature', the explanations in the W3C/OGC Spatial Data on the Web Best Practice document may help, in particular the section on Spatial Things, Features and Geometry.

4.4. feature collection

a set of **features** from a **dataset**

Chapter 5. Conventions

5.1. Identifiers

The normative provisions in this specification are denoted by the URI `http://www.opengis.net/spec/wfs-1/3.0`.

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

5.2. UML model

UML diagrams are included in this standard to illustrate the conceptual model that underpins Web Feature Service implementations. The UML model is not normative. The UML profile used is specified in ISO 19103:2015.

Resources are modelled as UML interfaces.

5.3. Link relations

To express relationships between resources, RFC 5988 (Web Linking) and registered link relation types are used.

5.4. Use of HTTPS

For simplicity, this document in general only refers to the HTTP protocol. This is not meant to exclude the use of HTTPS and simply is a shorthand notation for "HTTP or HTTPS". In fact, most WFS are expected to use HTTPS, not HTTP.

5.5. API definition

5.5.1. General remarks

Good documentation is essential for every API so that developers can learn how to use it. In the best case, documentation will be available in HTML and in a format that can be processed by software to connect to the API.

This standard specifies requirements and recommendations for APIs that share feature data and that want to follow a standard way of doing so. In general, APIs will go beyond the requirements and recommendations stated in this standard - or other parts of the Web Feature Service standard series - and will support additional operations, parameters, etc. that are specific to the API or the software tool used to implement the API.

5.5.2. Role of OpenAPI

This document uses OpenAPI 3.0 fragments as examples and to formally state requirements.

However, using OpenAPI 3.0 is not required.

The "Core" requirements class, therefore, only requires that an API definition is provided at /api.

A separate requirements class is specified for API definitions that follow the OpenAPI specification 3.0, but this does not preclude that in the future or in parallel other versions of OpenAPI or other descriptions are provided by a server.

NOTE	This approach is used to avoid lock-in to a specific approach to defining an API as it is expected that the landscape will continue to evolve.

In this document, fragments of OpenAPI definitions are shown in YAML since YAML is easier to read than JSON and is typically used in OpenAPI editors.

5.5.3. References to OpenAPI components in normative statements

Some normative statements (requirements, recommendations and permissions) use a phrase that a component in the API definition of the server must be "based upon" a schema or parameter component in the OGC schema repository.

In this case, the following changes to the pre-defined OpenAPI component are permitted:

- If the server supports an XML encoding, `xml` properties may be added to the relevant OpenAPI schema components.
- The range of values of a parameter or property may be extended (additional values) or constrained (if only a subset of all possible values are applicable to the service). An example for a constrained range of values is to explicitly specify the supported values of a string parameter or property using an enum.
- Additional properties may be added to the schema definition of a Response Object.
- Informative text may be changed or added, like comments or description properties.

NOTE	TODO Check, that we cover all cases.

For API definitions that do not conform to the OpenAPI Specification 3.0 the normative statement should be interpreted in the context of the API definition language used.

5.5.4. Paths in OpenAPI definitions

All paths in an OpenAPI definition are relative to a base URL of the server.

Example 1. URL of the OpenAPI definition

If the OpenAPI Server Object would look like this:

```
servers:
  - url: https://dev.example.org/
    description: Development server
  - url: https://data.example.org/
    description: Production server
```

The path "/mypath" in the OpenAPI definition of a WFS would be the URL `https://data.example.org/mypath` for the production server.

5.5.5. Reusable OpenAPI components

Reusable components for OpenAPI definitions of a WFS are referenced from this document.

NOTE	For now, these components use a base URL of "https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/", but eventually these will be available using the base URL "http://schemas.opengis.net/wfs/3.0/openapi/".

Chapter 6. Overview

6.1. Evolution from previous versions of WFS

The previous versions of the WFS standard used a Remote-Procedure-Call-over-HTTP architectural style using XML for any payloads as it was state-of-the-art in the late 1990s and early 2000s, when WFS was originally designed. This version specifies a modernized service, that follows the current Web architecture and in particular the W3C/OGC best practices for sharing Spatial Data on the Web as well as the W3C best practices for sharing Data on the Web.

Beside the general alignment with the architecture of the Web (e.g., consistency with HTTP/HTTPS, hypermedia controls), another goal is modularization. This has a few facets:

- Clear separation between core requirements that almost everyone has who wants to share or use spatial data on a fine-grained level (this document) and more advanced capabilities that communities are using today (extensions specified in additional parts of WFS 3.0).
- Technologies that change more frequently are decoupled and specified in separate modules ("requirements classes" in OGC terminology). This enables, for example, the use/re-use of new encodings for spatial data or API descriptions.
- Modularization is not just about WFS modules, but about providing building blocks for fine-grained access to spatial data that can be used in data APIs in general. In other words, a server supporting WFS 3.0 should not be seen as a standalone WFS service. A corollary of this is that it should be possible to implement a data API that at the same time conforms to conformance classes from WFS 3.0 and from other OGC Web Service standards following a similar approach.

This approach intends to support two types of client developers:

- those that have never heard about WFS - it should be possible to create a client using the API definition without the need to read the WFS standard (they may need to learn a little bit about geometry, etc.);
- those that want to write a "generic" client that can access WFSs, i.e. are not specific for a particular API/server.

As a result of this modernization, WFS 3.0 implementations are not backwards compatible with WFS 2.0 implementations per se. However, it has been a design goal to define WFS 3.0 in a way so that the WFS 3.0 interface can be mapped to a WFS 2.0 implementation. WFS 3.0 is intended to be simpler and more modern, but still an evolution from the previous versions and their implementations.

The modernization is discussed in more detail here.

NOTE	TODO Change this to a link to the WFS 3.0 Guide once a draft is available. Explain that the Guide includes a mapping between OGC Capabilities and OpenAPI as well as a mapping between WFS 2.0 operations and WFS 3.0.

6.2. Encodings

This standard does not mandate any encoding or format for representing features or feature collections. In addition to HTML as the standard encoding for Web content, rules for commonly used encodings for spatial data on the web are provided (GeoJSON, GML).

None of these encodings is mandatory and an implementation of the "Core" requirements class may also decide to use none of them, but to use another encoding instead.

Support for HTML is recommended as HTML is the core language of the World Wide Web. A server that supports HTML will support browsing the data with a web browser and it will enable search engines to crawl and index the dataset.

GeoJSON is a commonly used format that is simple to understand and well supported by tools and software libraries. Since most Web developers are comfortable with using a JSON-based format, this version of the Web Feature Service standard recommends to support GeoJSON for encoding feature data, if the feature data can be represented in GeoJSON for the intended use.

Some examples for cases that are out-of-scope of GeoJSON are:

- solids are used a geometries (e.g. in a 3D city model),
- geometries include non-linear curve interpolations that cannot be simplified (e.g., use of arcs in authoritative geometries),
- geometries have to be represented in a coordinate reference system that is not based on WGS 84 longitude/latitude (e.g. an authoritative national reference system),
- features have more than one geometric property, etc.

In addition to HTML and GeoJSON, a significant amount of feature data is available in XML-based formats, notably GML. GML supports more complex requirements than GeoJSON and does not have any of the limitations mentioned in the previous paragraph, but as a result GML also more complex to handle for both servers and clients. Conformance classes for GML are, therefore, included in this standard, but it is expected that these will typically be supported by servers where users are known to expect feature data in XML/GML.

The recommendations for HTML and GeoJSON reflect the importance of HTML and the current popularity of JSON-based data formats. As the practices in the Web community evolve, the recommendations will likely be updated, too, in future versions of this standard to provide guidance.

This part of WFS 3.0 does not provide any guidance on other encodings. The supported encodings, or more precisely the media types of the supported encodings, can be determined from the API definition. The desired encoding is selected using HTTP content negotiation.

For example, if the server supports GeoJSON Text Sequences, an encoding that is based on JSON text sequences and GeoJSON to support streaming by making the the data incrementally parseable, the media type `application/geo+json-seq` would be used.

In addition, HTTP supports compression and the standard HTTP mechanisms can be used to reduce the size of the messages between the server and the client.

6.3. Examples

This document uses a simple example throughout the document: The dataset contains buildings and the server provides access to them through a single feature collection ("buildings") and two encodings, GeoJSON and HTML.

The buildings have a few (optional) properties: the polygon geometry of the building footprint, a name, the function of the building (residential, commercial or public use) and the floor count.

Chapter 7. Requirement Class "Core"

7.1. Overview

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/core	
Target type	Web service
Dependency	RFC 2616 (HTTP/1.1)
Dependency	RFC 5988 (Web Linking)

Figure 1 illustrates the resources supported by the Core requirements class using UML. Each resource type available through the server is an «interface».

A server that implements the WFS API provides access to the features in a dataset. In other words, the API is a distribution of that dataset. A file download, for example, would be another distribution.

That is, each WFS has a single `LandingPage` (path `/`) that provides links to

- the `APIDefinition` (path `/api`),
- the `Conformance` statements (path `/conformance`),
- the `DatasetDistribution` metadata (path `/collections`).

The `APIDefinition` describes the capabilities of the server and which can be used by clients to connect to the server or by development tools to support the implementation of servers and clients. Accessing the `APIDefinition` using HTTP GET returns a description of the API.

Accessing the `Conformance` using HTTP GET returns a list of URIs of requirements classes implemented by the server.

The distribution consists of a set of feature collections. This specification does not include any requirements how the features in the dataset have to be aggregated into collections. A typical approach is to aggregate by feature type, but any other approach that fits the dataset or the applications using this distribution may be used, too.

Accessing the `DatasetDistribution` using HTTP GET returns a `DatasetDistributionResponse`, which includes a link to each `Collection` in the distribution along with metadata about each collection:

- a local identifier for the collection that is unique within the WFS;
- a list of coordinate reference systems in which geometries may be returned by the server, where the first one is the default coordinate reference system (in the Core, the default is always WGS 84 with axis order longitude/latitude);
- an optional title and description for the collection;
- an optional bounding box that can be used to provide an indication of the spatial extent of the collection - typically derived from the data.

Each `Collection` (path `/collections/{collection-name}/items`) consists of the features in the collection where each feature in the distribution is part of exactly one collection.

CAUTION	ISSUE 30 Allow also features that do not belong to any collection?

CAUTION	ISSUE 66 Support features that do belong to multiple collections?

Accessing a `Collection` using HTTP GET returns a `CollectionResponse`, which basically consists of features in the collection. The features included in the response are determined by the server based on parameters of the request.

A `bbox` parameter may be used to select only a subset of the features in the collection (the features that are located in the bounding box).

The `limit` parameter may be used to request only a subset of the selected features and to indicate that the client wants to page through the selected features of the collection.

The `CollectionResponse` may include metadata about the number of selected and returned features (`numberMatched` and `numberReturned`) as well as links to simplify paging (`next` and `prev`).

Each `Feature` (path `/collections/{collection-name}/items/{feature-id}`) is also a separate resource and may be requested individually using HTTP GET.

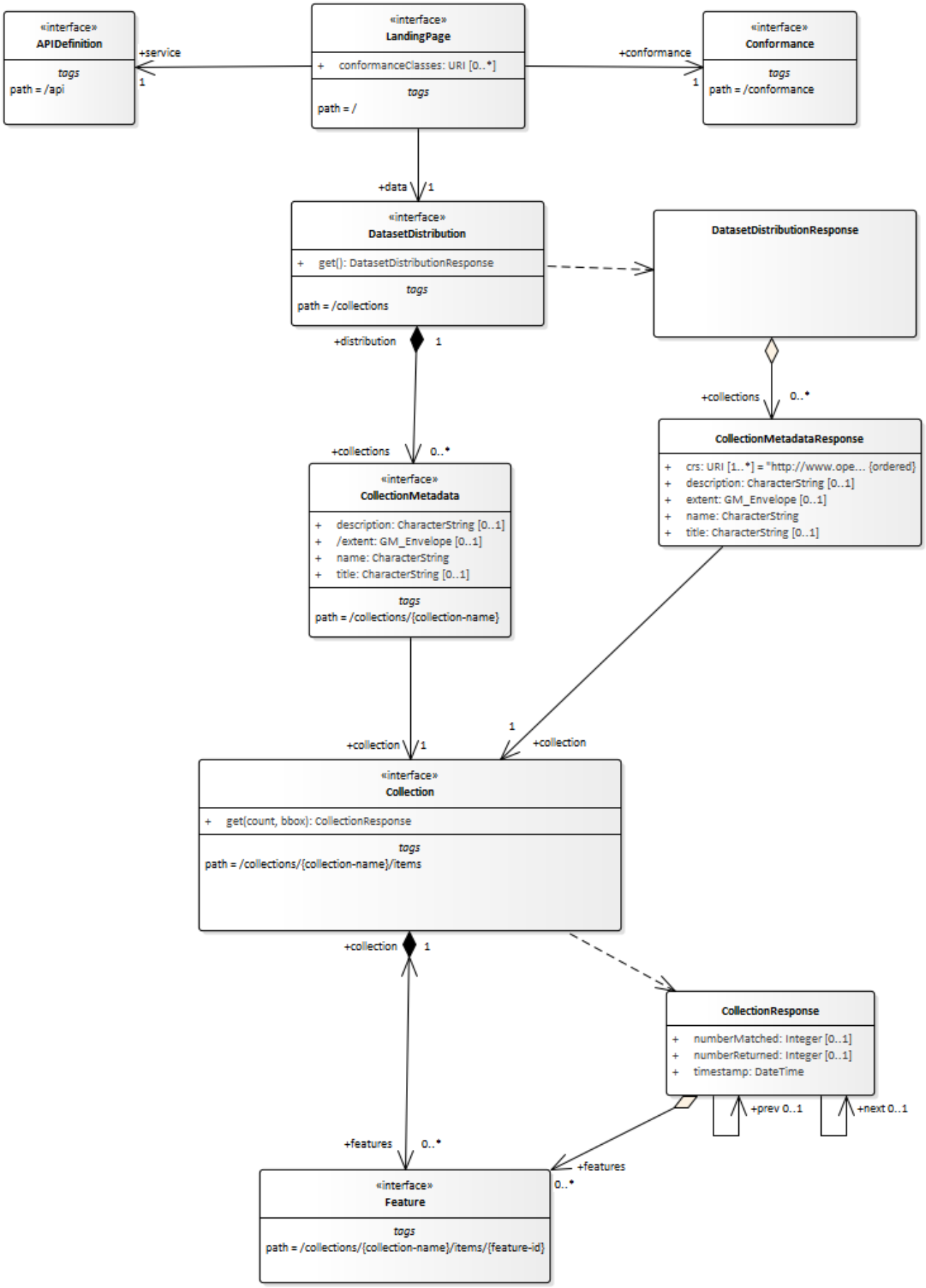

Figure 1. Resources in the Core requirements class

7.2. API landing page

7.2.1. Operation

Requirement 1	/req/core/root-op The server SHALL support the HTTP GET operation at the path `/`.

7.2.2. Response

Requirement 2	/req/core/root-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`. The content of that response SHALL be based upon the OpenAPI 3.0 schema root.yaml and include at least links to the following resources: • `/api` (relation type 'service') • `/conformance` (relation type 'conformance') • `/collections` (relation type 'data')

NOTE	TODO Check, if we can reuse existing relation types instead of 'conformance' and 'data'?

Schema for the landing page

```
type: object
required:
  - links
properties:
  links:
    type: array
    items:
      $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schemas/l
ink.yaml
```

Example 2. Landing page response document


```
{
  "links": [
    { "href": "http://data.example.org/",
      "rel": "self", "type": "application/json", "title": "this document" },
    { "href": "http://data.example.org/api",
      "rel": "service", "type": "application/openapi+json;version=3.0", "title":
"the API definition" },
    { "href": "http://data.example.org/conformance",
      "rel": "conformance", "type": "application/json", "title": "WFS 3.0
conformance classes implemented by this server" },
    { "href": "http://data.example.org/collections",
      "rel": "data", "type": "application/json", "title": "Metadata about the
feature collections" }
  ]
}
```


7.3. API definition

7.3.1. Operation

Every WFS provides an API definition that describes the capabilities of the server and which can be used by developers to understand the API, by software clients to connect to the server or by development tools to support the implementation of servers and clients.

Requirement 3	/req/core/api-definition-op The server SHALL support the HTTP GET operation at the path `/api`.

7.3.2. Response

Requirement 4	/req/core/api-definition-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`. The server SHALL return an API definition document.

Recommendation 1	/rec/core/api-definition-oas If the API definition document uses the OpenAPI Specification 3.0, the document SHOULD conform to the OpenAPI Specification 3.0 requirements class.

If multiple API definition formats are supported by a server, use content negotiation to select the desired representation.

The API definition document describes the API. I.e., there is no need to include the `/api` operation in the API definition itself.

The idea is that any WFS can be used by developers that are familiar with the API definition language(s) supported by the server. For example, if an OpenAPI definition is used, it should be possible to create a working client using the OpenAPI definition. The developer may need to learn a little bit about geometry, etc., but it should not be required to read this standard to access the data via the API.

7.4. Declaration of conformance classes

7.4.1. Operation

To support "generic" clients for accessing Web Feature Services in general - and not "just" a specific API / server, the server has to declare the requirements classes it implements and conforms to, too.

Requirement 5	/req/core/conformance-op The server SHALL support the HTTP GET operation at the path `/conformance`.

7.4.2. Response

Requirement 6	/req/core/conformance-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`. The content of that response SHALL be based upon the OpenAPI 3.0 schema req-classes.yaml and list all WFS 3.0 requirements classes that the server conforms to.

Schema for the list of requirements classes

```
type: object
required:
  - conformsTo
properties:
  conformsTo:
    type: array
    items:
      type: string
```

Example 3. Requirements class response document

This example response in JSON is for a server that supports OpenAPI 3.0 for the API definition and HTML and GeoJSON as encodings for features.

```
{
  "conformsTo": [
    "http://www.opengis.net/spec/wfs-1/3.0/req/core",
    "http://www.opengis.net/spec/wfs-1/3.0/req/oas30",
    "http://www.opengis.net/spec/wfs-1/3.0/req/html",
    "http://www.opengis.net/spec/wfs-1/3.0/req/geojson"
  ]
}
```

7.5. HTTP 1.1

Requirement 7	/req/core/http The server SHALL conform to HTTP 1.1.

This includes the correct use of status codes, headers, etc.

7.6. Web caching

Entity tags are a mechanism for web cache validation and for supporting conditional requests to reduce network traffic. Entity tags are specified by HTTP/1.1 (RFC 2616).

Recommendation 2	/rec/core/etag The service SHOULD support entity tags and the associated headers as specified by HTTP/1.1.

NOTE	TODO Add an example OpenAPI operation (headers, response codes). Here or in clause 9.

CAUTION	ISSUE 38 More detail / examples on caching

7.7. Support for cross-origin requests

To access data from a HTML page where the data is on another host than the webpage is by default prohibited for security reasons ("same-origin policy"). A typical example is a web-application accessing feature data from multiple distributed datasets.

Recommendation 3	/rec/core/cross-origin If the server is intended to be accessed from the browser, cross-origin requests SHOULD be supported. Note that support can also be added in a proxy layer on top of the server.

Two common mechanisms to support cross-origin requests are:

- Cross-origin resource sharing (CORS)
- JSONP (JSON with padding)

7.8. Encodings

While WFS 3.0 does not include any mandatory encoding, it recommends the following encodings. See Clause 6 (Overview) for a discussion.

Recommendation 4	/rec/core/html To support browsing a WFS with a web browser and to enable search engines to crawl and index a dataset, implementations SHOULD consider to support an HTML encoding.

Recommendation 5	/rec/core/geojson If the feature data can be represented for the intended use in GeoJSON, implementations SHOULD consider to support GeoJSON as an encoding for features and feature collections.

Requirement `/req/core/http` implies that the encoding of a server response is determined using content negotiation as specified by the HTTP specification.

The section Media Types includes guidance on media types for encodings that are specified in this document.

Note that any server that supports multiple encodings will have to support a mechanism to mint encoding-specific URIs for resources in order to express links, for example, to alternate representations of the same resource. This document does not mandate any particular approach how this is supported by the server.

As clients simply need to dereference the URI of the link, the implementation details and the mechanism how the encoding is included in the URI of the link are not important. Developers interested in the approach of a particular implementation, for example, to manipulate ("hack") URIs in the browser address bar, can study the API definition.

NOTE

Two common approaches are:

- an additional path for each encoding of each resource (this can be expressed, for example, using format specific suffixes like ".html");
- an additional query parameter (for example, "accept" or "f") that overrides the Accept header of the HTTP request.

7.9. Coordinate reference systems

As discussed in Chapter 9 of the W3C/OGC Spatial Data on the Web Best Practices, how to express and share the location of features in a consistent way is one of the most fundamental aspects of publishing geographic data and it is important to be clear about the coordinate reference system that coordinates are in.

For the reasons discussed in the Best Practices, Web Feature Service 3.0 uses WGS84 longitude and latitude as the default coordinate reference system.

Requirement 8	/req/core/crs84 Unless the client explicitly requests a different coordinate reference system, all spatial geometries SHALL be in the coordinate reference system http://www.opengis.net/def/crs/OGC/1.3/CRS84 (WGS84 longitude/latitude).

The Core does not specify a capability to request geometries in a different coordinate reference system. Such a capability will be specified in another part of the WFS 3.0 series.

7.10. Link headers

Recommendation 6	/rec/core/link-header Links included in payload of responses SHOULD also be included as `Link` headers in the HTTP response according to RFC 5988, Clause 5. This recommendation does not apply, if there are a large number of links included in a response or a link is not known when the HTTP headers of the response are created.

7.11. Feature collections metadata

7.11.1. Operation

Requirement 9	/req/core/fc-md-op The server SHALL support the HTTP GET operation at the path `/collections`.

7.11.2. Response

Requirement 10	/req/core/fc-md-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`. The content of that response SHALL be based upon the OpenAPI 3.0 schema content.yaml.

Schema for the metadata about feature collections

```
type: object
required:
  - links
  - collections
properties:
  links:
    type: array
    items:
      $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schemas/l
ink.yaml
  collections:
    type: array
    items:
      $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schemas/c
ollectionInfo.yaml
```

Requirement 11	/req/core/fc-md-links A `200`-response SHALL include the following links in the `links` property of the response: • a link to this response document (relation: `self`), • a link to the response document in every other media type supported by the server (relation: `alternate`), • links to each feature collection resource in this distribution of the dataset for each supported encoding (relation: `item`). All links SHALL include the `rel` and `type` link parameters.

Recommendation 7	/rec/core/fc-md-descriptions If external schemas or descriptions for the dataset exist that provide information about the structure or semantics of the data, a `200`-response SHOULD include links to each of those resources in the `links` property of the response (relation: `describedBy`). The `type` link parameter SHOULD be provided for each link. This applies to resources that describe to the whole dataset. For resources that describe the contents of a feature collection, the links SHOULD be set in the `links` property of the appropriate object in the `collections` resource. Examples for descriptions are: XML Schema, Schematron, JSON Schema, RDF Schema, OWL, SHACL, a feature catalogue, etc.

CAUTION	ISSUE 56 Lack of DescribeFeatureType request

NOTE	TODO Add recommendation about a link to the distribution resource in the dataset metadata (example in DCAT). Which link relation type?

Requirement 12	/req/core/fc-md-items For each feature collection in this distribution of the dataset, an item SHALL be provided in the property `collections`.

Requirement 13	/req/core/fc-md-links For each feature collection in this distribution of the dataset, the `links` property SHALL include an item for each supported encoding with a link to the collection resource (relation: `item`). All links SHALL include the `rel` and `type` properties.

NOTE	TODO Check, if we can/should make use of the new Link Object in OpenAPI 3.0.

Requirement 14	/req/core/fc-md-extent For each feature collection, the `extent` property, if provided, SHALL be a bounding box that includes all feature geometries in this collection.

Schema for the metadata about a feature collection

```
type: object
required:
  - name
  - links
properties:
  name:
    description: identifier of the collection used, for example, in URIs
    type: string
  title:
    description: human readable title of the collection
    type: string
  description:
    description: a description of the features in the collection
    type: string
  links:
    type: array
    items:
      $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schemas/l
ink.yaml
  extent:
    $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schemas/b
box.yaml
  crs:
    description: the list of coordinate reference systems supported by the service;
the first item is the default coordinate reference system
    type: array
    items:
      type: string
    default:
      - http://www.opengis.net/def/crs/OGC/1.3/CRS84
```

NOTE The `crs` property is not used by this conformance class, but reserved for future use.

Example 4. Feature collection metadata response document

This feature collection metadata example response in JSON is for a dataset with a single collection "buildings". It includes links to the collection resource in all formats that are supported by the service (link relation type: "item").

Representations of the metadata resource in other formats are referenced using link relation type "alternate".

Additional links to a GML application schema for the building data and to a web page that has additional information about buildings are provided, too, using link relation type "describedBy".

Coordinate reference system information is not provided as the service provides geometries only in the default system (WGS84 longitude/latitude).


```
{
  "links": [
    { "href": "http://data.example.org/collections.json",
      "rel": "self", "type": "application/json", "title": "this document" },
    { "href": "http://data.example.org/collections.html",
      "rel": "alternate", "type": "text/html", "title": "this document as HTML" },
    { "href": "http://schemas.example.org/1.0/foobar.xsd",
      "rel": "describedBy", "type": "application/xml", "title": "XML schema for
Acme Corporation data" }
  ],
  "collections": [
    {
      "name": "buildings",
      "title": "Buildings",
      "description": "Buildings in the city of Bonn.",
      "extent": {
        "bbox": [ 7.01, 50.63, 7.22, 50.78 ]
      },
      "links": [
        { "href": "http://data.example.org/collections/buildings/items",
          "rel": "item", "type": "application/geo+json",
          "title": "Buildings" }
        { "href": "http://example.org/concepts/building.html",
          "rel": "describedBy", "type": "text/html",
          "title": "Feature catalogue for buildings" }
      ]
    }
  ]
}
```

7.12. Feature collection metadata

7.12.1. Operation

Requirement 15	/req/core/sfc-md-op The server SHALL support the HTTP GET operation at the path `/collections/{name}`. `name` is the property of the same name in the feature collections metadata.

7.12.2. Response

Requirement 16	/req/core/sfc-md-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`. The content of that response SHALL be the same to the content for this feature collection in the `/collections` response.

7.13. Feature collections

7.13.1. Operation

Requirement 17	/req/core/fc-op For every feature collection identified in the metadata about the feature collection (path `/`), the server SHALL support the HTTP GET operation at the path `/collections/{name}/items`. `name` is the property of the same name in the feature collections metadata.

CAUTION	ISSUE 17 Precision level filter responsibility?

7.13.2. Parameter limit

Requirement 18	/req/core/fc-limit-definition
	
	Each feature collection operation SHALL support a parameter `limit` with the following characteristics (using an OpenAPI Specification 3.0 fragment):
	
	`name: limit`
	`in: query`
	`required: false`
	`schema:`
	`  type: integer`
	`  minimum: 1`
	`  maximum: 10000`
	`  default: 10`
	`style: form`
	`explode: false`

Permission 1	/per/core/fc-limit-default-maximum The values for `maximum` and `default` in requirement `/req/core/fc-limit-definition` are only examples and MAY be changed.

Requirement 19	/req/core/fc-limit-response-1 The response SHALL not contain more features than specified by the optional `limit` parameter. If the API definition specifies a maximum value for `limit` parameter, the response SHALL not contain more features than this maximum value. Only items are counted that are on the first level of the collection. Any nested objects contained within the explicitly requested items SHALL not be counted.

Permission 2	/per/core/fc-limit-response-2 The server MAY return less features than requested (but not more).

A template for the definition of the parameter in YAML according to OpenAPI 3.0 is available at limit.yaml.

7.13.3. Parameter bbox

Requirement 20	/req/core/fc-bbox-definition
	
	Each feature collection operation SHALL support a parameter `bbox` with the following characteristics (using an OpenAPI Specification 3.0 fragment):
	
	`name: bbox`
	`in: query`
	`required: false`
	`schema:`
	`  type: array`
	`  minItems: 4`
	`  maxItems: 4`
	`  items:`
	`  type: number`
	`  minimum: -180`
	`  maximum: 180`
	`style: form`
	`explode: false`

Requirement 21	/req/core/fc-bbox-response Only features that have a geometry that intersects the bounding box SHALL be part of the result set, if the `bbox` parameter is provided. The bounding box is provided as four numbers: • Lower left corner, coordinate axis 1 • Lower left corner, coordinate axis 2 • Upper right corner, coordinate axis 1 • Upper right corner, coordinate axis 2

For WGS84 longitude/latitude this is in most cases the sequence of minimum longitude, minimum latitude, maximum longitude and maximum latitude. However, in cases where the box spans the antimeridian the first value (west-most box edge) is larger than the third value (east-most box edge).

Example 5. The bounding box of the New Zealand Exclusive Economic Zone

The bounding box of the New Zealand Exclusive Economic Zone in WGS84 (from 160.6°E to 170°W and from 55.95°S to 25.89°S) would be represented in JSON as `[ 160.6, -55.95, -170, -25.89 ]`.

A template for the definition of the parameter in YAML according to OpenAPI 3.0 is available at

bbox.yaml.

7.13.4. Parameters for filtering on feature properties

CAUTION	ISSUE 20 Query parameter collisions.

Recommendation 8	/rec/core/fc-filters
	
	If features in the feature collection include a feature property that has a simple value (for example, a string or integer) that is expected to be useful for applications using the service to filter the features of the collection based on this property, you SHOULD support a parameter with the name of the feature property and with the following characteristics (using an OpenAPI Specification 3.0 fragment):
	
	`in: query`
	`required: false`
	`style: form`
	`explode: false`
	
	The `schema` property SHALL be the same as the definition of the feature property in the response schema.

Example 6. An additional parameter to filter buildings based on their function

```
name: function
in: query
description: >-
  Only return buildings of a particular function.\

  Default = return all buildings.
required: false
schema:
  type: string
  enum:
    - residential
    - commercial
    - public use
style: form
explode: false
example: 'function=public+use'
```

Example 7. An additional parameter to filter buildings based on their name

```
name: name
in: query
description: >-
  Only return buildings with a particular name. Use '*' as a wildcard.\

  Default = return all buildings.
required: false
schema:
  type: string
style: form
explode: false
example: 'name=A*'
```

For string-valued properties, servers could support wildcard searches. The example included in the OpenAPI fragment would search for all buildings with a name that starts with "A".

7.13.5. Response

Requirement 22	/req/core/fc-response A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`.

The response will only include features selected by the request.

The number of features returned depends on the server and the parameter `limit`:

- The client can request a limit it is interested in.
- The server likely has a default value for the limit, and a maximum limit.
- If the server has any more results available than it returns (the number it returns is less than or equal to the requested/default/maximum limit) then the server will include a link to the next set of results.

So (using the default/maximum values of 10/10000 from the OpenAPI fragment in requirement `/req/core/fc-limit-definition`):

- If you ask for 10, you will get 0 to 10 (as requested) and a `next` link, if there are more.
- If you don't specify a limit, you will get 0 to 10 (default) and a `next` link, if there are more.
- If you ask for 50000, you might get up to 10000 (server-limited) and a `next` link, if there are more.
- If you follow the next link from the previous response, you might get up to 10000 additional features and a `next` link, if there are more.

Requirement 23	/req/core/fc-links A `200`-response SHALL include the following links: • a link to this response document (relation: `self`), • a link to the response document in every other media type supported by the service (relation: `alternate`).

Recommendation 9	/rec/core/fc-next-1 A `200`-response SHOULD include a link to the next "page" (relation: `next`), if more features have been selected than returned in the response.

Recommendation 10	/rec/core/fc-next-2 Dereferencing a `next` link SHOULD return additional features from the set of selected features that have not yet been returned.

Recommendation 11	/rec/core/fc-next-2 The number of features in a response to a `next` link SHOULD follow the same rules as for the response to the original query and again include a `next` link, if there are more features in the selection that have not yet been returned.

This document does not mandate any specific implementation approach for the `next` links.

An implementation could use opaque links that are managed by the server. It is up to the server to determine how long these links can be de-referenced. Clients should be prepared to receive a 404 response.

Another implementation approach is to use an implementation-specific parameter like the `startIndex` parameter that was used in previous versions of WFS (and which may be added again in an extension to this specification).

Permission 3	/per/core/fc-prev A response to a `next` link MAY include a `prev` link to the resource that included the `next` link.

Providing `prev` links supports navigating back and forth between pages, but depending on the implementation approach it may be complex to implement.

Requirement 24	/req/core/fc-rel-type All links SHALL include the `rel` and `type` link parameters.

NOTE The representation of the links in the payload will depend on the encoding of the feature collection.

Example 8. Links

If the request is to return building features and "10" is the default `limit`, the links in the response could be (in this example represented as link headers and using an additional parameter `startIndex` to implement `next` links - and the optional `prev` links):

```
Link: <http://data.example.org/collections/buildings/items.json>; rel="self";
type="application/geo+json"
Link: <http://data.example.org/collections/buildings/items.html>; rel="alternate";
type="text/html"
Link: <http://data.example.org/collections/buildings/items.json?startIndex=10>;
rel="next"; type="application/geo+json"
```

Following the `next` link could return:

```
Link: <http://data.example.org/collections/buildings/items.json?startIndex=10>;
rel="self"; type="application/geo+json"
Link: <http://data.example.org/collections/buildings/items.html?startIndex=10>;
rel="alternate"; type="text/html"
Link: <http://data.example.org/collections/buildings/items.json?startIndex=0>;
rel="prev"; type="application/geo+json"
Link: <http://data.example.org/collections/buildings/items.json?startIndex=20>;
rel="next"; type="application/geo+json"
```

If an explicit `limit` of "50" is used, the links in the response could be:

```
Link: <http://data.example.org/collections/buildings/items.json?limit=50>;
rel="self"; type="application/geo+json"
Link: <http://data.example.org/collections/buildings/items.html?limit=50>;
rel="alternate"; type="text/html"
Link:
<http://data.example.org/collections/buildings/items.json?limit=50&startIndex=50>;
rel="next"; type="application/geo+json"
```

Following the `next` link could return:

```
Link:
<http://data.example.org/collections/buildings/items.json?limit=50&startIndex=50>;
rel="self"; type="application/geo+json"
Link:
<http://data.example.org/collections/buildings/items.html?limit=50&startIndex=50>;
rel="alternate"; type="text/html"
Link:
<http://data.example.org/collections/buildings/items.json?limit=50&startIndex=0>;
rel="prev"; type="application/geo+json"
Link:
<http://data.example.org/collections/buildings/items.json?limit=50&startIndex=100>
; rel="next"; type="application/geo+json"
```

NOTE

TODO
Add normative statements for the following information in the response:

- timeStamp: Indicates the time and date when the response was generated.
- numberMatched: The number of features of the feature type that match the selection parameters like `bbox` or additional filter parameters.
- numberReturned: If the value is provided, the value shall be identical to the number of items in the "features" array. A server may omit this information in a response, if the information about the number of features is not known or difficult to compute. If the value of the resultType parameter is set to "hits", the value shall be set to "0", if provided.

CAUTION

Related to ISSUE 8
Define these as headers or include them in the payload? `timeStamp`, for example, does not seem to be needed given the 'Date' HTTP header. For `numberMatched` and `numberReturned` headers do not seem to be a good idea as, for example, `numberReturned` can only be included at the end, if streaming is used.

7.14. Feature

7.14.1. Operation

Requirement 25	/req/core/f-op For every feature in a feature collection (path `/collections/{name}/items`), the service SHALL support the HTTP GET operation at the path `/collections/{name}/items/{id}`. `name` is the property of the same name in the feature collection metadata. `id` is the unique identifier of the feature within the dataset.

NOTE TODO
Add more about the feature identifiers.

CAUTION ISSUE 47
There are two types of Feature Identifier and we need to make sure we distinguish between them.

7.14.2. Response

Requirement 26	/req/core/f-success A successful execution of the operation SHALL be reported as a response with a HTTP status code `200`.

Requirement 27	/req/core/f-links A `200`-response SHALL include the following links in the response: • a link to the response document (relation: `self`), • a link to the response document in every other media type supported by the service (relation: `alternate`), and • a link to the feature collection that contains this feature (relation: `collection`). All links SHALL include the `rel` and `type` link parameters.

NOTE The representation of the links in the payload will depend on the encoding of the feature collection.

Example 9. Links

The links in a feature could be (in this example represented as link headers):

```
Link: <http://data.example.org/collections/buildings/items/123.json>; rel="self";
type="application/geo+json"
Link: <http://data.example.org/collections/buildings/items/123.html>;
rel="alternate"; type="text/html"
Link: <http://data.example.org/collections/buildings/items.json>;
rel="collection"; type="application/geo+json"
```

Chapter 8. Requirements classes for encodings

8.1. Overview

This clause specifies four pre-defined requirements classes for encodings to be used in a WFS. These encodings are commonly used encodings for spatial data on the web:

- HTML
- GeoJSON
- Geography Markup Language (GML), Simple Features Profile, Level 0
- Geography Markup Language (GML), Simple Features Profile, Level 2

None of these encodings is mandatory and an implementation of the Core requirements class may also decide to use none of them, but to use another encoding instead.

The Core requirements class includes recommendations to support HTML and GeoJSON as encodings, where practical. Clause 6 (Overview) includes a discussion about recommended encodings.

8.2. Requirement Class "HTML"

Geographic information that is only accessible in formats like GeoJSON or GML has two issues:

- it is not discoverable using the most common mechanism for discovering information, that is the search engines of the Web;
- it can not be viewed directly in a browser - additional tools are required to view the data.

Therefore, sharing data on the Web should include publication in HTML. To be consistent with the Web, it should be done in a way that enables users and search engines to access all data.

This is discussed in detail in Best Practice 2: Make your spatial data indexable by search engines [SDWBP]. This standard therefore recommends to support HTML as an encoding.

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/html	
Target type	Web service
Dependency	WFS 3.0 Core
Dependency	HTML5
Dependency	Schema.org

Requirement 28	/req/html/definition Every `200`-response of an operation of the server SHALL support the media type `text/html`.

Requirement 29	/req/html/content Every `200`-response of the server with the media type "text/html" SHALL be a HTML 5 document that includes the following information in the HTML body: • all information identified in the schemas of the Response Object in the HTML `<body/>`, and • all links in HTML `<a/>` elements in the HTML `<body/>`.

Recommendation 12	/rec/html/schema-org In a `200`-response with the media type `text/html`, SHOULD include Schema.org annotations.

8.3. Requirement Class "GeoJSON"

GeoJSON is a commonly used format that is simple to understand and well supported by tools and software libraries. Since most Web developers are comfortable with using a JSON-based format, supporting GeoJSON is recommended, if the feature data can be represented in GeoJSON for the intended use.

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/geojson	
Target type	Web service
Dependency	WFS 3.0 Core
Dependency	GeoJSON

Requirement 30	/req/geojson/definition `200`-responses of the server SHALL support the following media types: • `application/geo+json` for feature collections and features, and • `application/json` for all other resources.

Requirement 31	/req/geojson/content Every `200`-response with the media type `application/geo+json` SHALL be • a GeoJSON FeatureCollection Object for feature collections, and • a GeoJSON Feature Object for features. The links specified in the requirements `/req/core/fc-links` and `/req/core/f-links` SHALL be added in a extension property (foreign member) with the name `links`.

Templates for the definition of the schemas for the GeoJSON responses in OpenAPI definitions are available at featureCollectionGeoJSON.yaml and featureGeoJSON.yaml. These are generic schemas that do not include any application schema information about specific feature types or their properties.

Example 10. A GeoJSON FeatureCollection Object response

In the example below, only the first and tenth feature is shown. Coordinates are not shown.

```
{
  "type" : "FeatureCollection",
  "links" : [ {
    "href" : "http://data.example.com/collections/buildings/items/?f=json",
    "rel" : "self",
    "type" : "application/geo+json",
    "title" : "this document"
  }, {
    "href" : "http://data.example.com/collections/buildings/items/?f=html",
    "rel" : "alternate",
    "type" : "text/html",
    "title" : "this document as HTML"
  }, {
    "href" :
"http://data.example.com/collections/buildings/items/?f=json&startIndex=10&limit=1
0",
    "rel" : "next",
    "type" : "application/geo+json",
    "title" : "next page"
  } ],
  "features" : [ {
    "type" : "Feature",
    "id" : "123",
    "geometry" : {
      "type" : "Polygon",
      "coordinates" : [ ... ]
    },
    "properties" : {
      "function" : "residential",
      "floors" : "2"
    }
  }, { ...
  }, {
    "type" : "Feature",
    "id" : "132",
    "geometry" : {
      "type" : "Polygon",
      "coordinates" : [ ... ]
    },
    "properties" : {
      "function" : "public use",
      "floors" : "10"
    }
  } ]
}
```

Example 11. A GeoJSON Feature Object response

In the example below, coordinates are not shown.


```
{
  "type" : "Feature",
  "links" : [ {
    "href" : "http://data.example.com/collections/buildings/items/123/?f=json",
    "rel" : "self",
    "type" : "application/geo+json",
    "title" : "this document"
  }, {
    "href" : "http://data.example.com/collections/buildings/items/123/?f=html",
    "rel" : "alternate",
    "type" : "text/html",
    "title" : "this document as HTML"
  }, {
    "href" : "http://data.example.com/collections/buildings/items",
    "rel" : "collection",
    "type" : "application/geo+json",
    "title" : "the collection document"
  } ],
  "id" : "123",
  "geometry" : {
    "type" : "Polygon",
    "coordinates" : [ ... ]
  },
  "properties" : {
    "function" : "residential",
    "floors" : "2"
  }
}
```


8.4. Requirement Class "Geography Markup Language (GML), Simple Features Profile, Level 0"

In addition to HTML and GeoJSON, a significant amount of feature data is available in XML-based formats, notably GML. Therefore, this standard specifies requirement classes for GML. The Simple Features Profile, Level 0, is the simplest profile of GML and is typically supported by tools. It is restricted to data with 2D geometries supported by most tools. In addition, the profile is limited to features that can be stored in a tabular data structure.

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/gmlsf0	
Target type	Web service
Dependency	WFS 3.0 Core

Dependency	Geography Markup Language (GML), Simple Features Profile, Level 0

Requirement 32	/req/gmlsf0/definition `200`-responses of the server SHALL support the following media types: • `application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf0` for feature collections and features, • `application/xml` for all other resources.

Requirement 33	/req/gmlsf0/content Every `200`-response with the media type `application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf0` SHALL be • a WFS 3.0 Core FeatureCollection Object for feature collections, and • a GML 3.2 Feature for features. Every feature SHALL conform to the GML Simple Features Profile, Level 0.

NOTE	TODO The WFS 3.0 Core FeatureCollection Object has to be an XML schema element defined according to 8.4.2 Defining feature collections. Add statements how links are represented.

Templates for the definition of the schemas for the GML responses in OpenAPI definitions are available at featureCollectionGML.yaml and featureGML.yaml. These are generic schemas that do not include any application schema information about specific feature types or their properties.

8.5. Requirement Class "Geography Markup Language (GML), Simple Features Profile, Level 2"

The difference between this requirement class and the Level 0 requirements class is that non-spatial feature properties are not restricted to atomic values (strings, numbers, etc.).

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/gmlsf2	
Target type	Web service
Dependency	WFS 3.0 Core

Dependency	Geography Markup Language (GML), Simple Features Profile, Level 2

Requirement 34	/req/gmlsf2/definition 200-responses of the server SHALL support the following media types: • application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf2 for feature collections and features, • application/xml for all other resources.

Requirement 35	/req/gmlsf2/content Every 200-response with the media type application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf2 SHALL be • a WFS 3.0 Core FeatureCollection Object for feature collections, and • a GML 3.2 Feature for features. Every feature SHALL conform to the GML Simple Features Profile, Level 2.

Chapter 9. Requirements class "OpenAPI 3.0"

9.1. Basic requirements

The API of servers conforming to this requirements class are defined by an OpenAPI Document.

Requirements Class	
http://www.opengis.net/spec/wfs-1/3.0/req/oas30	
Target type	Web service
Dependency	WFS 3.0 Core
Dependency	OpenAPI Specification 3.0.1

Requirement 36	/req/oas30/oas-definition-1 The service SHALL provide an OpenAPI definition in JSON and HTML at the path `/api` using the media type `application/openapi+json;version=3.0`.

Requirement 37	/req/oas30/oas-definition-2 The JSON representation SHALL conform to the OpenAPI Specification, version 3.0.

An example OpenAPI document is included in Annex B.

Requirement 38	/req/oas30/oas-impl The server SHALL implement all capabilities specified in the OpenAPI definition.

NOTE	Currently, no tool is known to validate that a server implements the API specified in its OpenAPI definition.

CAUTION	ISSUE 46 OpenAPI Validation

9.2. Complete definition

Requirement 39	/req/oas30/completeness The OpenAPI definition SHALL specify for each operation all HTTP Status Codes and Response Objects that the server uses in responses. This includes the successful execution of an operation as well as all error situations that originate from the server.

Note that servers that, for example, are access-controlled (see Security), that support web cache validation, CORS or that use HTTP redirection will make use of additional HTTP status codes beyond regular codes like `200` for successful GET requests and `400`, `404` or `500` for error situations.

NOTE	TODO Check, if the approach is consistent with the security concepts identified in the upcoming "OGC Web Services Security" standard.

Clients should be prepared to receive responses not documented in the OpenAPI definition. For example, additional errors may occur in the transport layer outside of the server.

9.3. Exceptions

Requirement 40	/req/oas30/exceptions-codes For error situations that originate from the server, the API definition SHALL cover all applicable HTTP Status Codes.

CAUTION	ISSUE 45 Listing of all applicable HTTP Status Codes

Requirement 41	/req/oas30/exceptions-400 For error situations that are the result of a bad request by the client, error code `400` SHALL be used.

NOTE	TODO Add list of pre-defined WFS error codes for 400-responses, including MissingParameterValue, InvalidParameterValue, OperationParsingFailed.

Requirement 42	/req/oas30/exceptions-500 For error situations that are the result of an internal server error, error code `500` SHALL be used.

NOTE	TODO Add list of pre-defined WFS error codes for 500-responses, including NoApplicableCode, OperationProcessingFailed.

Example 12. An exception response object definition

```
description: An error occurred.
content:
  application/json:
    schema:
      $ref:
https://raw.githubusercontent.com/opengeospatial/WFS_FES/master/core/openapi/schem
as/exception.yaml
  text/html:
    schema:
      type: string
```

9.4. Security

Requirement 43	/req/oas30/security For cases, where the operations of the server are access-controlled, the security scheme(s) SHALL be documented in the OpenAPI definition.

The OpenAPI specification currently supports the following security schemes:

- HTTP authentication,
- an API key (either as a header or as a query parameter),
- OAuth2's common flows (implicit, password, application and access code) as defined in RFC6749, and
- OpenID Connect Discovery.

CAUTION	ISSUE 41 How does a client determine which security protocols/standards/etc. a server supports

9.5. Feature collection metadata

Requirement 44	/req/oas30/fc-md-op The `operationId` of the HTTP GET operation for feature collection metadata SHALL be "describeCollections".

9.6. Feature collections

Recommendation 13	/rec/oas30/fc-key-properties The schema for the Response Objects of the HTTP GET operation for feature collections SHOULD include key feature properties of the features in the feature collection. This is in particular helpful, if filter parameters are defined for the collection (see recommendation `/rec/core/fc-filters`).

9.7. Features

Recommendation 14	/rec/oas30/f-key-properties The schema for the Response Objects of the HTTP GET operation for features SHOULD include key feature properties of the features.

Chapter 10. Media Types

JSON media types that would typically be used in a WFS that supports JSON are

- `application/json` for feature collection metadata, and
- `application/geo+json` for feature collections and features.

XML media types that would typically occur in a WFS that supports XML are

- `application/xml` for feature collection metadata,
- `application/gml+xml;version=3.2` for any GML 3.2 feature collections and features,
- `application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf0` for GML 3.2 feature collections and features conforming to the GML Simple Feature Level 0 profile, and
- `application/gml+xml;version=3.2;profile=http://www.opengis.net/def/profile/ogc/2.0/gml-sf2` for GML 3.2 feature collections and features conforming to the GML Simple Feature Level 2 profile.

The typical HTML media type for all "web pages" in a WFS would be `text/html`.

The media type for an OpenAPI definition in JSON is `application/openapi+json;version=3.0`.

NOTE	The media type for the OpenAPI definition has not yet been registered with IANA. See https://github.com/OAI/OpenAPI-Specification/issues/110.

Annex A: Conformance Class Abstract Test Suite (Normative)

NOTE TODO

CAUTION ISSUE 46
OpenAPI Validation

Annex B: OpenAPI definition example (Informative)

This annex includes a complete example of an OpenAPI definition for a WFS.

```
openapi: 3.0.0
info:
  title: A sample API conforming to the OGC Web Feature Service standard
  version: 0.0.1
  description: >-
    This is a sample OpenAPI definition that conforms to the OGC Web Feature Service
specification (conformance classes: "Core", "GeoJSON", "HTML" and "OpenAPI 3.0").
  contact:
    name: Acme Corporation
    email: info@example.org
    url: http://example.org/
  license:
    name: CC-BY 4.0 license
    url: https://creativecommons.org/licenses/by/4.0/
servers:
  - url: https://dev.example.org/
    description: Development server
  - url: https://data.example.org/
    description: Production server
paths:
  /:
    get:
      summary: landing page of this API
      description: >-
        The landing page provides links to the API definition,
        the Conformance statements and the metadata about the
        building data in this dataset.
      operationId: getLandingPage
      tags:
        - Capabilities
      responses:
        '200':
          description: links to the API capabilities
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/root'
            text/html:
              schema:
                type: string
  /conformance:
    get:
      summary: information about standards that this API conforms to
      description: >-
```

```
      list all requirements classes specified in a standard
      (e.g., WFS 3.0 Part 1: Core) that the server conforms to
    operationId: getRequirementsClasses
    tags:
      - Capabilities
    responses:
      '200':
        description: the URIs of all requirements classes supported by the server
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/req-classes'
      default:
        description: An error occured.
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/exception'
/collections:
  get:
    summary: describe the feature collections in the dataset
    operationId: describeCollections
    tags:
      - Capabilities
    responses:
      '200':
        description: Metdata about the feature collections shared by this API.
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/content'
          text/html:
            schema:
              type: string
      default:
        description: An error occured.
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/exception'
          text/html:
            schema:
              type: string
/collections/buildings:
  get:
    summary: describe the building feature collection
    operationId: describeCollectionBuildings
    tags:
      - Capabilities
    responses:
      '200':
```

```
          description: Metadata about the buildings shared by this API.
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/collectionInfo'
            text/html:
              schema:
                type: string
        default:
          description: An error occured.
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/exception'
            text/html:
              schema:
                type: string
  /collections/buildings/items:
    get:
      summary: retrieve building features
      description: >-
        Every feature in a dataset belongs to a collection. A dataset may
        consist of multiple feature collections. A feature collection is
        often a collection of features of a similar type, based on a
        common schema.\

        This sample WFS has a single feature collection for buildings.\

        Use content negotiation to request HTML or GeoJSON.
      operationId: getBuildings
      tags:
        - Features
      parameters:
        - $ref: '#/components/parameters/limit'
        - $ref: '#/components/parameters/bbox'
        - $ref: '#/components/parameters/function'
      responses:
        '200':
          description: >-
            Information about the feature collection plus the first features matching
the selection parameters.
          content:
            application/geo+json:
              schema:
                $ref: '#/components/schemas/featureCollectionGeoJSON'
            text/html:
              schema:
                type: string
        default:
          description: An error occured.
          content:
```

```
            application/json:
              schema:
                $ref: '#/components/schemas/exception'
            text/html:
              schema:
                type: string
  /collections/buildings/items.json:
    get:
      summary: retrieve building features in GeoJSON
      description: >-
        Every feature in a dataset belongs to a collection. A dataset may
        consist of multiple feature collections. A feature collection is
        often a collection of features of a similar type, based on a
        common schema.\

        This sample WFS has a single feature collection for buildings.
      operationId: getBuildingsJSON
      tags:
        - Features
      parameters:
        - $ref: '#/components/parameters/limit'
        - $ref: '#/components/parameters/bbox'
        - $ref: '#/components/parameters/function'
      responses:
        '200':
          description: >-
            Information about the feature collection plus the first features matching
the selection parameters.
          content:
            application/geo+json:
              schema:
                $ref: '#/components/schemas/featureCollectionGeoJSON'
        default:
          description: An error occured.
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/exception'
  /collections/buildings/items/{fid}:
    get:
      summary: retrieve a building; use content negotiation to request HTML or GeoJSON
      operationId: getBuilding
      tags:
        - Features
      parameters:
        - $ref: '#/components/parameters/id'
      responses:
        '200':
          description: A feature.
          content:
            application/geo+json:
```

```
              schema:
                $ref: '#/components/schemas/buildingGeoJSON'
            text/html:
              schema:
                type: string
        default:
          description: An error occured.
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/exception'
            text/html:
              schema:
                type: string
  /collections/buildings/items/{fid}.json:
    get:
      summary: retrieve a building in GeoJSON
      operationId: getBuildingJSON
      tags:
        - Features
      parameters:
        - $ref: '#/components/parameters/id'
      responses:
        '200':
          description: A feature.
          content:
            application/geo+json:
              schema:
                $ref: '#/components/schemas/buildingGeoJSON'
        default:
          description: An error occured.
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/exception'
components:
  parameters:
    limit:
      name: limit
      in: query
      description: >-
        The optional limit parameter limits the number of items that are presented in
the response document.\

        Only items are counted that are on the first level of the collection in the
response document.
        Nested objects contained within the explicitly requested items shall not be
counted.\

        Minimum = 1.\
```

```
        Maximum = 10000.\

        Default = 10.
      required: false
      schema:
        type: integer
        minimum: 1
        maximum: 10000
        default: 10
      style: form
      explode: false
    bbox:
      name: bbox
      in: query
      description: >-
        Only features that have a geometry that intersects the bounding box are
selected. The bounding box is provided as four numbers:

        * Lower left corner, coordinate axis 1
        * Lower left corner, coordinate axis 2
        * Upper right corner, coordinate axis 1
        * Upper right corner, coordinate axis 2

        For WGS84 longitude/latitude this is in most cases the sequence of
        minimum longitude, minimum latitude, maximum longitude and maximum latitude.
        However, in cases where the box spans the antimeridian the first value
        (west-most box edge) is larger than the third value (east-most box edge).
      required: false
      schema:
        type: array
        minItems: 4
        maxItems: 4
        items:
          type: number
          minimum: -180
          maximum: 180
      style: form
      explode: false
    function:
      name: function
      in: query
      description: >-
        Only return buildings of a particular function.\

        Default = return all buildings.
      required: false
      schema:
        type: string
        enum:
          - residential
          - commercial
```

```
          - public use
      style: form
      explode: false
      example: 'function=public+use'
    id:
      name: id
      in: path
      description: The id of a feature
      required: true
      schema:
        type: string
  schemas:
    exception:
      type: object
      required:
        - code
      properties:
        code:
          type: string
        description:
          type: string
    root:
      type: object
      required:
        - links
      properties:
        links:
          type: array
          items:
            $ref: link.yaml
    req-classes:
      type: object
      required:
        - conformsTo
      properties:
        conformsTo:
          type: array
          items:
            type: string
          example:
            - http://www.opengis.net/spec/wfs-1/3.0/req/core
            - http://www.opengis.net/spec/wfs-1/3.0/req/oas30
            - http://www.opengis.net/spec/wfs-1/3.0/req/html
            - http://www.opengis.net/spec/wfs-1/3.0/req/geojson
    bbox:
      type: object
      required:
        - bbox
      properties:
        crs:
          type: string
```

```
        enum:
          - http://www.opengis.net/def/crs/OGC/1.3/CRS84
        default: http://www.opengis.net/def/crs/OGC/1.3/CRS84
      bbox:
        description: west, north, east, south edges of the bounding box
        type: array
        minItems: 4
        maxItems: 4
        items:
          type: number
          minimum: -180
          maximum: 180
        example:
          - -180
          - -90
          - 180
          - 90
content:
  type: object
  required:
    - collections
  properties:
    collections:
      type: array
      items:
        $ref: '#/components/schemas/collectionInfo'
collectionInfo:
  type: object
  required:
    - name
    - links
  properties:
    name:
      type: string
      example: address
    title:
      type: string
      example: address
    description:
      type: string
      example: An address.
    links:
      type: array
      items:
        $ref: '#/components/schemas/link'
      example:
        - href: http://data.example.com/buildings
          rel: item
        - href: http://example.com/concepts/buildings.html
          rel: describedBy
          type: text/html
```

```
      extent:
        $ref: '#/components/schemas/bbox'
      crs:
        description: >-
          The coordinate reference systems in which geometries
          may be retrieved. Coordinate reference systems are identified
          by a URI. The first coordinate reference system is the
          coordinate reference system that is used by default. This
          is always "http://www.opengis.net/def/crs/OGC/1.3/CRS84", i.e.
          WGS84 longitude/latitude.
        type: array
        items:
          type: string
        default:
          - http://www.opengis.net/def/crs/OGC/1.3/CRS84
        example:
          - http://www.opengis.net/def/crs/OGC/1.3/CRS84
          - http://www.opengis.net/def/crs/EPSG/0/4326
  link:
    type: object
    required:
      - href
    properties:
      href:
        type: string
        example: http://data.example.com/buildings/123
      rel:
        type: string
        example: alternate
      type:
        type: string
        example: application/geo+json
      hreflang:
        type: string
        example: en
  featureCollectionGeoJSON:
    type: object
    required:
      - features
    properties:
      features:
        type: array
        items:
          $ref: '#/components/schemas/featureGeoJSON'
  featureGeoJSON:
    type: object
    required:
      - type
      - geometry
      - properties
    properties:
```

```
      type:
        type: string
        enum:
          - Feature
      geometry:
        $ref: '#/components/schemas/geometryGeoJSON'
      properties:
        type: object
        nullable: true
      id:
        oneOf:
          - type: string
          - type: integer
  geometryGeoJSON:
    type: object
    required:
      - type
    properties:
      type:
        type: string
        enum:
          - Point
          - MultiPoint
          - LineString
          - MultiLineString
          - Polygon
          - MultiPolygon
          - GeometryCollection
  buildingGeoJSON:
    type: object
    required:
      - type
      - geometry
      - properties
    properties:
      type:
        type: string
        enum:
          - Feature
      geometry:
        $ref: '#/components/schemas/geometryGeoJSON'
      properties:
        type: object
        nullable: true
        properties:
          name:
            type: string
          function:
            type: string
            enum:
              - residential
```

```
                - commercial
                - public use
            floors:
              type: integer
              minimum: 1
tags:
  - name: Capabilities
    description: Essential characteristics of this API including information about the
data.
  - name: Features
    description: Access to data (features).
```

Annex C: Revision History

Date	Release	Editor	Primary clauses modified	Description
2017-10-09	SNAPSHOT	C. Portele	all	initial version
2017-10-11	SNAPSHOT	C. Portele	all	changes discussed in SWG/PT call on 2017-10-09
2017-12-13	SNAPSHOT	C. Portele	all	address issues #2, #5, #6, #7, #8, #14, #15, #19
2018-01-22	SNAPSHOT	C. Portele	7	add description of the UML diagram
2018-02-01	SNAPSHOT	C. Portele	2,3,5,7	add links to recent issues on GitHub; address issues #31, #32
2018-02-11	SNAPSHOT	C. Portele	2,6,7,8	address issue #25
2018-02-27	SNAPSHOT	C. Portele	all	address issues #3, #9, #12, #22, #23, #24, #44; add links to issues #41, #45, #46, #47
2018-03-04	SNAPSHOT	T. Schaub	7,B	JSON schema fixes #54, #55
2018-03-11	SNAPSHOT	C. Portele	all	Updates after the WFS 3.0 Hackathon #59, #61, #62, #63, #64, #69; resolve #4; editorial edits

Annex D: Bibliography

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