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OGC Route Exchange Model

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i. Abstract

TODO

ii. Keywords

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

OGC, Routing, Route Exchange Model

iii. Preface

TODO: Insert Preface Text here. Give OGC specific commentary: describe the technical content, reason for document, history of the document and precursors, and plans for future work.

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iv. Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

Organization name(s)

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

Name Affiliation

TODO

Chapter 1. Scope

TODO: Insert Scope text here. Give the subject of the document and the aspects of that scope covered by the document.

Chapter 2. Conformance

TODO

This Standard defines XXXX.

Requirements for N standardization target types are considered:

- AAAA
- BBBB

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.

In order to conform to this OGC® Standard, a software implementation shall choose to implement:

- Any one of the conformance levels specified in Annex A (normative).
- Any one of the Distributed Computing Platform profiles specified in Annexes TBD through TBD (normative).

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

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.

- Internet Engineering Task Force (IETF). RFC 3339: **Date and Time on the Internet: Timestamps** [online]. Edited by G. Klyne, C. Newman. 2002 [viewed 2020-03-16]. Available at http://tools.ietf.org/rfc/rfc3339.txt
- Internet Engineering Task Force (IETF). RFC 7946: **The GeoJSON Format** [online]. Edited by H. Butler, M. Daly, A. Doyle, S. Gillies, S. Hagen, T. Schaub. 2016 [viewed 2020-03-16]. Available at http://tools.ietf.org/rfc/rfc7946.txt

Chapter 4. Terms and Definitions

This document used the terms defined in OGC Policy Directive 49, 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 and OGC documents do not use the equivalent phrases in the ISO/IEC Directives, Part 2.

This document also uses terms defined in the OGC Standard for Modular specifications (OGC 08-131r3), also known as the 'ModSpec'. The definitions of terms such as standard, specification, requirement, and conformance test are provided in the ModSpec.

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

TODO

term name

text of the definition

term name

text of the definition

Chapter 5. Conventions

This section provides details and examples for any conventions used in the document.

5.1. Identifiers

The normative provisions in this Standard are denoted by the URI

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

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

5.2. JSON schema

This document uses JSON Schema to document the syntax of the Route Exchange Model.

The complete schema is available in JSON schema of the Route Exchange Model in GeoJSON.

Chapter 6. Overview of the Route model

6.1. Scenarios

The Route model is driven by three routing scenarios. These were:

- Online - fully connected with stability
- Intermittent - unreliable connection
- Offline - no connectivity

6.1.1. Online scenario

In the Online scenario, an operator uses a routing client to request a route from a Routing API provider, which in turn retrieves the route from an online routing engine. In this scenario all components have consistent connections between them and out to the wider internet.

This scenario uses OGC API Routes for all request and response handling between the client and the routing infrastructure.

6.1.2. Intermittent scenario

The intermittent scenario is where the components have connectivity, but it is not necessarily consistent, stable, reliable, or high-speed.

Therefore, the network cannot be relied upon to provide connectivity on demand and compensation actions are likely when connectivity is not available. Intermittent connectivity is unpredictable and it maybe that in the real-world, decisions are made to treat intermittent connectivity as no connectivity, as it is the only sensible course of action, especially if the scenario involves threat to life.

For example, only one of the clients had access to a routing engine. Therefore, the connected client had the ability to create routes, but other clients cannot. If the clients are able to communicate with each other via some other means (Bluetooth or some other peer-to-peer communication, for example), the clients could still share pre-defined routes, that is, the routing operation has been completed when a connection to the routing engine was established, but has now been lost.

Another approach to support in particular low-bandwidth situations is to not transmit the complete route definition to the client, but to return route information segment by segment as the vehicle moves along the route.

6.1.3. Offline scenario

The Offline scenario assumes that there is no connectivity outside of a device’s local network, this could be a desktop computer, mobile device or a mesh. In the real-world the scenario is modeling an instance where there is no connectivity and there is not going to be any connectivity for the duration of an operation.

An operator uses the routing functionality provided by the client to create a route. The operator

then shares this route with other local clients using the route exchange model. To enable the required functionality, all of the capability has to be tightly coupled in a single location. Practically, this involves installing all of the components on the same machine to remove communication dependencies with the wider network.

6.2. The Route model

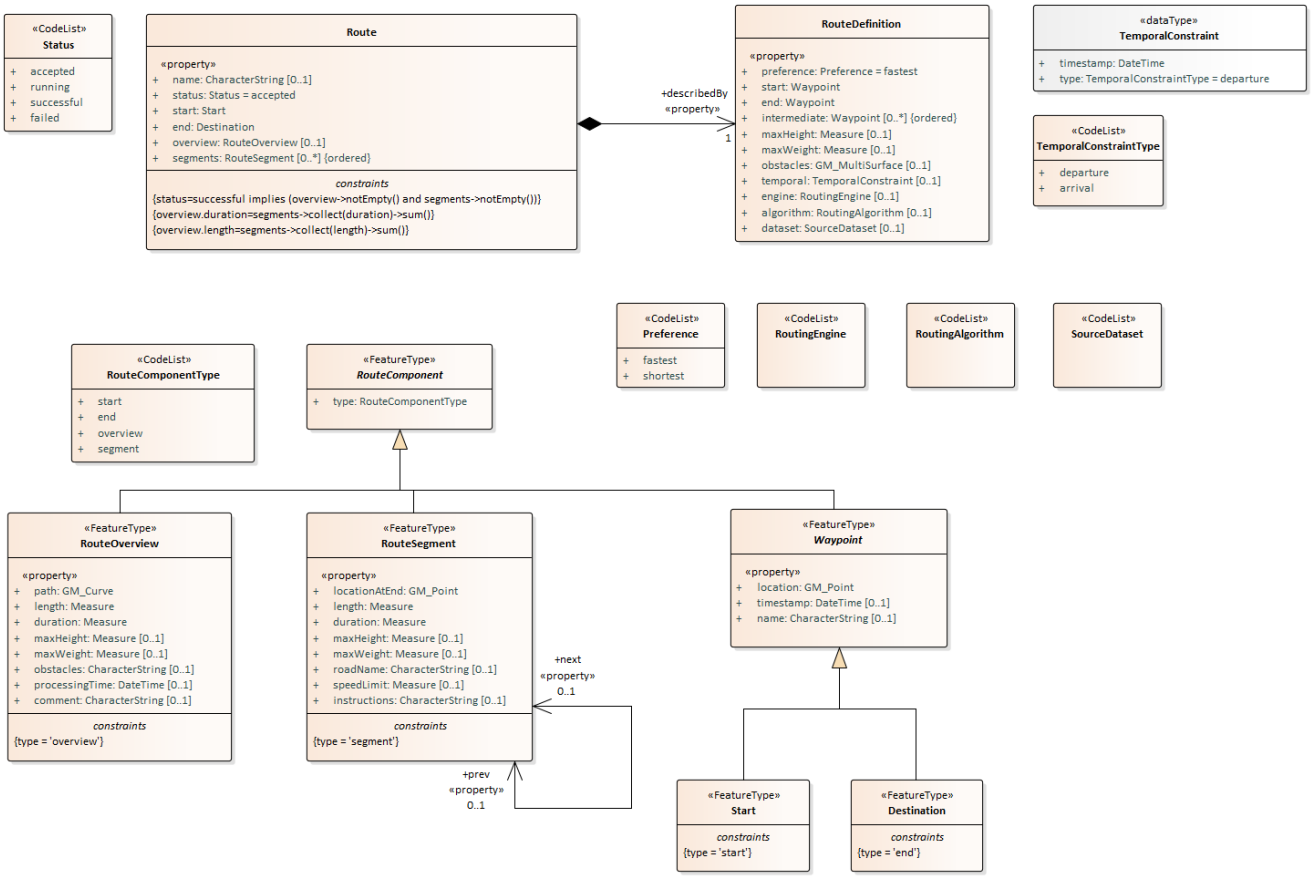

Figure 1. UML class diagram of the Route model

6.2.1. Destination

- a subtype of `Waypoint`
- a `Feature`
- constraints:
  - `type = 'end'`

6.2.2. Route

- an `Object`
- association role `describedBy`
  - multiplicity: 1
  - value: `RouteDefinition`
- attribute `end`

    - definition: The end point of the route.
    - multiplicity: 1
    - value: `Destination`
- attribute `name`
    - definition: Title of the route.
    - multiplicity: 0..1
    - value: `CharacterString`
- attribute `overview`
    - multiplicity: 0..1
    - value: `RouteOverview`
- attribute `segments`
    - multiplicity: 0..*
    - value: `RouteSegment`
- attribute `start`
    - definition: The start point of the route.
    - multiplicity: 1
    - value: `Start`
- attribute `status`
    - definition: Processing status of the route.
    - multiplicity: 1
    - default: accepted
    - values:
        - `accepted`: The route is queued for processing.
        - `running`: The route is being computed.
        - `successful`: The route is available.
        - `failed`: The route could not be computed.
- constraints:
    - `overview.duration=segments→collect(duration)→sum()`
    - `overview.length=segments→collect(length)→sum()`
    - `status=successful implies (overview→notEmpty() and segments→notEmpty())`

6.2.3. RouteComponent

- a supertype of `RouteOverview`, `RouteSegment`, `Waypoint`
- a `Feature`
- is abstract

- attribute `type`
  - multiplicity: 1
  - values:
    - `start`
    - `end`
    - `overview`
    - `segment`

6.2.4. RouteDefinition

- a `Object`
- definition: Information about the definition of the route. At a minimum, a route is defined by two waypoints, the start and end point of the route.
- attribute `algorithm`
  - definition: Select the routing / graph solving algorithm to use for calculating the route.
  - multiplicity: 0..1
  - value: `RoutingAlgorithm`
- attribute `dataset`
  - definition: The name of the source dataset with a transport network used for calculating the route.
  - multiplicity: 0..1
  - value: `SourceDataset`
- attribute `end`
  - multiplicity: 1
  - value: `Waypoint`
- attribute `engine`
  - definition: The name of the routing engine used for calculating the route.
  - multiplicity: 0..1
  - value: `RoutingEngine`
- attribute `intermediate`
  - definition: Additional waypoints along the route between start and end to consider when computing the route.
  - multiplicity: 0..*
  - value: `Waypoint`
- attribute `maxHeight`
  - definition: A height restriction for vehicles in meters to consider when computing the route.
  - multiplicity: 0..1

    - value: `Measure`
- attribute `maxWeight`
    - definition: A weight restriction for vehicles in tons to consider when computing the route.
    - multiplicity: 0..1
    - value: `Measure`
- attribute `obstacles`
    - definition: Areas the route should avoid.
    - note: Currently this uses a simple approach. In general, the list of obstacles could also be a feature collection where every obstacle is a feature. Such a representation would be required, if the routing engine is able to handle obstacles with different characteristics/properties (for example, an obstacle is only valid for a certain time interval).
    - multiplicity: 0..1
    - value: `GM_MultiSurface`
- attribute `preference`
    - definition: The optimization goal for the route calculation (fastest, shortest, etc.).
    - multiplicity: 1
    - default: `fastest`
    - values:
        - `fastest`
        - `shortest`
        - ...
- attribute `start`
    - multiplicity: 1
    - value: `Waypoint`
- attribute `temporal`
    - definition: The time of departure or arrival. The default value is an immediate departure.
    - multiplicity: 0..1
    - value: `TemporalConstraint`

6.2.5. RouteOverview

- a subtype of `RouteComponent`
- a `Feature`
- attribute `comment`
    - definition: Explains any minor issues that were encountered during the processing of the routing request, i.e. any issues that did not result in an error.
    - multiplicity: 0..1

    - value: `CharacterString`
- attribute `duration`
    - definition: Estimated amount of time required to travel the route (in seconds).
    - multiplicity: 1
    - value: `Measure`
- attribute `length`
    - definition: Length of the route (in meters).
    - multiplicity: 1
    - value: `Measure`
- attribute `maxHeight`
    - definition: A known height restriction on the route (in meters).
    - multiplicity: 0..1
    - value: `Measure`
- attribute `maxWeight`
    - definition: A known weight restriction on the route (in tons).
    - multiplicity: 0..1
    - value: `Measure`
- attribute `obstacles`
    - definition: Describes how obstacles were taken into account in the route calculation.
    - multiplicity: 0..1
    - value: `CharacterString`
- attribute `path`
    - definition: The path from the start point to the end point of the route.
    - multiplicity: 1
    - value: `GM_Curve`
- attribute `processingTime`
    - definition: The time when the route was calculated.
    - multiplicity: 0..1
    - value: `DateTime`
- constraints:
    - `type = 'overview'`

6.2.6. RouteSegment

- a subtype of `RouteComponent`
- a `Feature`

- attribute `duration`
  - definition: Estimated amount of time required to travel the segment (in seconds).
  - multiplicity: 1
  - value: `Measure`
- attribute `instructions`
  - definition: An instruction for the maneuver at the end of the segment.
  - multiplicity: 0..1
  - value: `CharacterString`
- attribute `length`
  - definition: Length of the segment(in meters).
  - multiplicity: 1
  - value: `Measure`
- attribute `locationAtEnd`
  - definition: The last position of the segment and be on the path geometry of the route overview.
  - multiplicity: 1
  - value: `GM_Point`
- attribute `maxHeight`
  - definition: A known height restriction(in meters).
  - multiplicity: 0..1
  - value: `Measure`
- attribute `maxWeight`
  - definition: A known weight restriction (in tons).
  - multiplicity: 0..1
  - value: `Measure`
- association role `next`
  - multiplicity: 0..1
  - value: `RouteSegment`
- association role `prev`
  - multiplicity: 0..1
  - value: `RouteSegment`
- attribute `roadName`
  - definition: The road/street name of the segment.
  - multiplicity: 0..1
  - value: `CharacterString`

- attribute `speedLimit`
  - definition: A known speed limit on the segment.
  - multiplicity: 0..1
  - value: `Measure`
- constraints:
  - `type = 'segment'`

6.2.7. Start

- a subtype of `Waypoint`
- a `Feature`
- constraints:
  - `type = 'start'`

6.2.8. TemporalConstraint

- a `Data type`
- attribute `timestamp`
  - multiplicity: 1
  - value: `DateTime`
- attribute `type`
  - multiplicity: 1
  - default: `departure`
  - values:
    - `departure`
    - `arrival `

6.2.9. Waypoint

- a subtype of `RouteComponent`
- a supertype of `Destination`, `Start`
- a `Feature`
- definition: A waypoint of the route.
- attribute `location`
  - definition: The coordinates of the waypoint.
  - multiplicity: 1
  - value: `GM_Point`
- attribute `name`

    - definition: A name for the waypoint.
    - multiplicity: 0..1
    - value: `CharacterString`
- attribute `timestamp`
    - multiplicity: 0..1
    - value: `DateTime`

Chapter 7. Route Exchange Model

7.1. Overview

This document specifies a single encoding of the Route model described in the previous clause for the creation and transfer of route information between a variety of routing components ("Route Exchange Model"). The encoding uses GeoJSON to represent routes according to the model described above and is defined in the next clause.

A GeoJSON feature collection is used to represent the Route. Each RouteComponent is represented by a GeoJSON feature in the feature collection of the route.

GeoJSON is used for the following reasons:

- lightweight
- extensible
- widely supported in libraries and tools
- consistent with the emerging OGC API standards
- an open standard

The Route Exchange Model supports three variants:

- Full: All route information is encoded in a GeoJSON feature collection.
- Overview: A single GeoJSON feature detailing the route geometry along the network and the main properties of the route.
- Segments: The first segment of a route and a link to the second segment, if there is more than one segment in the route. Subsequent segments will contain a link to the previous and next segment. The final segment contains only a link to the previous segment. Each segment is a GeoJSON feature.

All implementations need to support the first variant (Full). The other two variants provide additional functionality to support a variety of use cases, specifically the Denied, Degraded, Intermittent and Low Bandwidth (DDIL) network use cases. Both options allow the user to retrieve the minimal information required for their use case. This could be the current step of the route, or an overview to assess the suggested route. In both cases only small GeoJSON objects are passed over the DDIL network. These variants also provide the option to conduct a comprehensive assessment of routes thereby allowing the user to request a number of route overviews in quick succession, choose the route which is most preferable and then reuse the route definition of the chosen route to request the full route.

The following sections in this clause below specifies the requirements classes that implementations need to conform to.

7.2. Requirements class "Route Exchange Model (core)"

This requirement class states requirements that apply to all representations of a route.

The normative statements use JSON Schema to specify schema components.

Requirements Class	
http://www.opengis.net/spec/rem/1.0/req/rem	
Target type	JSON object
Dependency	GeoJSON
Dependency	Date and Time on the Internet: Timestamps

Requirement 1	**/req/rem/geojson**
A	Every representation of a route SHALL be a valid GeoJSON object.

Requirement 2	**/req/rem/date-time**
A	Every representation of a timestamp SHALL be a valid `date-time` value according to RFC 3339, 5.6.

7.3. Requirements class "Route Exchange Model (full)"

This requirements class specifies the complete representation of a route, i.e., a representation that includes all information about the route.

See Sample route for an example of a full route.

Requirements Class	
http://www.opengis.net/spec/rem/1.0/req/rem-full	
Target type	JSON object
Dependency	Requirements class "Route Exchange Model (core)"
Dependency	Requirements class "Route Exchange Model (overview)"
Dependency	Requirements class "Route Exchange Model (segment)"

Requirement 3	**/req/rem-full/fc**
A	The complete representation of a route SHALL be a valid GeoJSON feature collection.

Recommendation 1	/rec/rem-full/fc-name
A	The feature collection SHOULD have a member with the name "name" that is a title of the route with the following schema: `{ "type": "string" }`

Typically the name will be provided by the requester of the route.

Requirement 4	/req/rem-full/fc-status
A	The feature collection SHALL have a member with the name "status" describing the processing status of the route with the following schema: `{ "type": "string", "enum": [ "accepted", "running", "successful", "failed" ] }`

The values are defined as follows:

accepted

The routing job is queued for execution.

running

The route is being computed.

successful

The route is available.

failed

The route could not be computed.

Requirement 5	/req/rem-full/fc-features

A	The feature collection SHALL contain the following features, depending on the status: • a route overview (see Requirements class "Route Exchange Model (overview)", only for status `successful`) • the start point of the route (see Requirement "start point") • the end point of the route (see Requirement "end point") • one or more segments (see Requirements class "Route Exchange Model (segment)", only for status `successful`)
B	The sequence of the segments SHALL be in their order along the route.

Recommendation 2	**/rec/rem-full/fc-links**
A	The feature collection SHOULD have a member with the name "links" with the following schema: `{ "type": "array", "items": { "type": "object", "required": [ "href" ], "properties": { "href": { "type": "string" }, "rel": { "type": "string" }, "type": { "type": "string" }, "hreflang": { "type": "string" }, "title": { "type": "string" } } } }`
B	There SHOULD be a link with • `rel` with value `self` • `type` with value `application/geo+json` • a URI to fetch the route in `href`

C	There SHOULD be a link with • `rel` with value `describedBy` • `type` with value `application/json` • a URI to fetch information about the definition of the route (start and end point, constraints) in `href`

Requirement 6	**/req/rem-full/start**
A	The start point of the route SHALL be a GeoJSON feature with a Point geometry.
B	The feature SHALL have a property `type` with the value `start`.
C	The point geometry of the feature SHALL depend on the status of the route: • "successful": identical to the first point of the route overview. • otherwise: identical to the start point in the definition of the route.
D	If the feature has a property `timestamp`, it SHALL be of type `string`, format `date-time`, and indicate the (estimated) departure time.

Requirement 7	**/req/rem-full/end**
A	The end point of the route SHALL be a GeoJSON feature with a Point geometry.
B	The feature SHALL have a property `type` with the value `end`.
C	The point geometry of the feature SHALL depend on the status of the route: • "successful": identical to the last point of the route overview and identical to the point in the last segment. • otherwise: identical to the end point in the definition of the route.
D	If the feature has a property `timestamp`, it SHALL be of type `string`, format `date-time`, and indicate the (estimated) arrival time.

7.4. Requirements class "Route Exchange Model (overview)"

Requirements Class	
http://www.opengis.net/spec/rem/1.0/req/rem-overview	
Target type	JSON object
Dependency	Requirements class "Route Exchange Model (core)"

Requirement 8	/req/rem-overview/feature
A	The route overview SHALL be a GeoJSON feature with a LineString geometry.
B	The feature SHALL have a property `type` with the value `overview`.
C	The line string geometry of the feature SHALL be the path from the start point to the end point of the route.
D	The feature SHALL have a property `length_m` (type: `number`) with the length of the segment (in meters).
E	The feature SHALL have a property `duration_s` (type: `number`) with the estimated amount of time required to travel the segment (in seconds).
F	If the feature has a property `maxHeight_m`, the value SHALL be of type `number` with a known height restriction on the route (in meters).
G	If the feature has a property `maxLoad_t`, the value SHALL be of type `number` with a known load restriction on the route (in tons).
H	If the feature has a property `obstacles`, the value SHALL be of type `string` and describe how obstacles were taken into account in the route calculation.
I	If the feature has a property `processingTime`, it SHALL be a `date-time` as specified by RFC 3339, 5.6 and state the time when the route was calculated.

J	If the feature has a property `comment`, the value SHALL be of type `string` and explain any minor issues that were encountered during the processing of the routing request, i.e. any issues that did not result in an error.

Recommendation 3	**/rec/rem-overview/properties**
A	The route overview SHOULD have the property `processingTime`.
B	If the process that creates the route has access to the information, the route overview SHOULD have the properties `maxHeight_m`, `maxLoad_t`, and `obstacles`.

7.5. Requirements class "Route Exchange Model (segment)"

Requirements Class	
http://www.opengis.net/spec/rem/1.0/req/rem-segment	
Target type	JSON object
Dependency	Requirements class "Route Exchange Model (core)"

Requirement 9	**/req/rem-segment/feature**
A	Each segment of the route SHALL be a GeoJSON feature with a Point geometry.
B	The segment feature SHALL have a property `type` with the value `segment`.
C	The point geometry of the feature SHALL be the last position of the segment and be on the line string geometry of the route overview.
D	The feature SHALL have a property `length_m` (type: `number`) with the length of the segment (in meters).
E	The feature SHALL have a property `duration_s` (type: `number`) with the estimated amount of time required to travel the segment (in seconds).

F	The sum of all `length_m` values of segments SHALL be identical to the `length_m` value in the route overview.
G	The sum of all `duration_s` values of segments SHALL be identical to the `duration_s` value in the route overview.
H	If the feature has a property `maxHeight_m`, the value SHALL be of type `number` with a known height restriction on the segment (in meters).
I	If the feature has a property `maxLoad_t`, the value SHALL be of type `number` with a known load restriction on the segment (in tons).
J	If the feature has a property `speedLimit`, the value SHALL be of type `integer` with a known speed limit on the segment.
K	If the feature has a property `speedLimit`, the unit of the speed limit SHALL be specified in a property `speedLimitUnit`; the allowed values are `kmph` (kilometers per hour) and `mph` (miles per hour).
L	If the feature has a property `roadName`, the value SHALL be of type `string` with the road/street name of the segment.
M	If the feature has a property `roadName` and the feature is part of a response to a HTTP(S) request, the language SHALL be specified in the `Content-Language` header.
N	If the feature has a property `instructions`, the value SHALL be of type `string` with an instruction for the maneuver at the end of the segment. Allowed values are `continue`, `left` and `right`.

7.6. Requirements class "Route Exchange Model (segment with links)"

Requirements Class	
http://www.opengis.net/spec/rem/1.0/req/rem-segment-with-links	
Target type	JSON object
Dependency	Requirements class "Route Exchange Model (segment)"

Requirement 10	**/req/rem-segment-with-links/next-prev**

A	Each segment SHALL have a member with the name `links with the following schema:  `{ "type": "array", "items": { "type": "object", "required": ["href"], "properties": { "href": { "type": "string" }, "rel": { "type": "string" }, "type": { "type": "string" }, "hreflang": { "type": "string" }, "title": { "type": "string" } } } }`
B	Unless the segment is the last segment of the route, the segment SHALL have a link • `rel` with value `next` • `type` with value `application/geo+json` • a URI to fetch the next segment along the route in `href`
C	Unless the segment is the first segment of the route, the segment SHALL have a link • `rel` with value `prev` • `type` with value `application/geo+json` • a URI to fetch the previous segment along the route in `href`

Chapter 8. Media Types

TODO: Use application/geo+json and do not register a new media type (for interoperability with consumers that know GeoJSON and its media type).

Annex A: Conformance Class Abstract Test Suite (Normative)

TODO

Annex B: JSON Schema (Normative)

This annex contains the JSON Schema of the Route Exchange Model in GeoJSON.

Example 1. JSON schema of the Route Exchange Model in GeoJSON

```
{
   "TODO": true
}
```

Annex C: Examples (Informative)

The following example of a "full" route also includes JSON-LD annotations to associate the JSON structures with GeoJSON and Route vocabularies.

Example 2. Sample route


```
{
    "@context": {
        "@version": 1.1,
        "geojson": "https://purl.org/geojson/vocab#",
        "rte":
"https://raw.githubusercontent.com/ogcincubator/route/master/route#",
        "Feature": "geojson:Feature",
        "FeatureCollection": "geojson:FeatureCollection",
        "GeometryCollection": "geojson:GeometryCollection",
        "LineString": "geojson:LineString",
        "MultiLineString": "geojson:MultiLineString",
        "MultiPoint": "geojson:MultiPoint",
        "MultiPolygon": "geojson:MultiPolygon",
        "Point": "geojson:Point",
        "Polygon": "geojson:Polygon",
        "bbox": {
            "@container": "@list",
            "@id": "geojson:bbox"
        },
        "coordinates": {
            "@container": "@list",
            "@id": "geojson:coordinates"
        },
        "features": {
            "@container": "@set",
            "@id": "geojson:features"
        },
        "geometry": "geojson:geometry",
        "id": "@id",
        "properties": "@nest",
        "name": "rdfs:label",
        "status": "rte:status",
        "length_m": "rte:length",
        "duration_s": "rte:duration",
        "instructions": "rte:instructions",
        "text": "rte:text",
        "roadName": "rte:roadName"
    },
    "type": "FeatureCollection",
    "id": "https://api.example.com/v1/routes/4711",
    "@type": [
        "geojson:FeatureCollection",
        "rte:Route"
    ],
    "name": "National Cathedral to Washington Monument",
    "status": "successful",
    "features": [
        {
```

```
            "id": "1",
            "@type": [
                "geojson:Feature",
                "rte:RouteOverview"
            ],
            "type": "Feature",
            "properties": {
                "type": "overview",
                "length_m": 8290,
                "duration_s": 1053
            },
            "geometry": {
                "type": "LineString",
                "coordinates": [
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                    [
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                    [
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                    [
```

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                    -77.0329356,
                    38.8899279
                ],
                [
                    -77.0330107,
                    38.890121
                ]
            ]
        },
        "bbox": [
            -77.0731902,
            38.8867736,
            -77.0328605,
            38.9309657
        ]
```

```
        },
        {
            "id": "2",
            "@type": [
                "geojson:Feature",
                "rte:Start"
            ],
            "type": "Feature",
            "properties": {
                "type": "start"
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0721,
                    38.9309
                ]
            }
        },
        {
            "id": "3",
            "@type": [
                "geojson:Feature",
                "rte:Segment"
            ],
            "type": "Feature",
            "properties": {
                "type": "segment",
                "levelOfDetail": "visualization",
                "length_m": 70,
                "duration_s": 46,
                "instructions": "continue",
                "text": "Head north on North Rd. Go for 70 m."
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0721011,
                    38.9308998
                ]
            }
        },
        {
            "id": "4",
            "@type": [
                "geojson:Feature",
                "rte:Segment"
            ],
            "type": "Feature",
            "properties": {
                "type": "segment",
```

```
            "levelOfDetail": "visualization",
            "length_m": 372,
            "duration_s": 75,
            "roadName": "North Rd",
            "instructions": "left",
            "text": "Turn left onto Wisconsin Ave NW. Go for 372 m."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
                -77.0728254,
                38.9308584
            ]
        }
    },
    {
        "id": "5",
        "@type": [
            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 131,
            "duration_s": 28,
            "roadName": "Wisconsin Ave NW",
            "instructions": "left",
            "text": "Turn left onto Garfield St NW. Go for 131 m."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
                -77.0731902,
                38.9275324
            ]
        }
    },
    {
        "id": "6",
        "@type": [
            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 1752,
            "duration_s": 215,
```

```
            "roadName": "Garfield St NW",
            "instructions": "right",
            "text": "Turn right onto Massachusetts Ave NW. Go for 1.8 km."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
                -77.0716774,
                38.9275324
            ]
        }
    },
    {
        "id": "7",
        "@type": [
            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 351,
            "duration_s": 49,
            "roadName": "Massachusetts Ave NW",
            "instructions": "right",
            "text": "Turn right onto Waterside Dr NW. Go for 351 m."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
                -77.057333,
                38.9170396
            ]
        }
    },
    {
        "id": "8",
        "@type": [
            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 3021,
            "duration_s": 275,
            "roadName": "Waterside Dr NW",
            "instructions": "continue",
            "text": "Take ramp onto Rock Creek and Potomac Pkwy NW. Go for 3.0
```

```
km."
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0559275,
                    38.9146042
                ]
            }
        },
        {
            "id": "9",
            "@type": [
                "geojson:Feature",
                "rte:Segment"
            ],
            "type": "Feature",
            "properties": {
                "type": "segment",
                "levelOfDetail": "visualization",
                "length_m": 748,
                "duration_s": 90,
                "roadName": "Rock Creek and Potomac Pkwy NW",
                "text": "Keep left onto Ohio Dr SW. Go for 748 m."
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0551014,
                    38.8923419
                ]
            }
        },
        {
            "id": "10",
            "@type": [
                "geojson:Feature",
                "rte:Segment"
            ],
            "type": "Feature",
            "properties": {
                "type": "segment",
                "levelOfDetail": "visualization",
                "length_m": 1155,
                "duration_s": 107,
                "roadName": "Ohio Dr SW",
                "text": "Keep left onto Independence Ave SW. Go for 1.2 km."
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
```

```
                -77.0513678,
                38.8873851
            ]
        }
    },
    {
        "id": "11",
        "@type": [
            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 125,
            "duration_s": 22,
            "roadName": "Independence Ave SW",
            "text": "Keep right onto Independence Ave SW. Go for 125 m."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
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                38.8869452
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        }
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        "id": "12",
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            "geojson:Feature",
            "rte:Segment"
        ],
        "type": "Feature",
        "properties": {
            "type": "segment",
            "levelOfDetail": "visualization",
            "length_m": 283,
            "duration_s": 73,
            "roadName": "Independence Ave SW",
            "text": "Keep left onto Independence Ave SW. Go for 283 m."
        },
        "geometry": {
            "type": "Point",
            "coordinates": [
                -77.0367014,
                38.8869452
            ]
        }
    },
```

```
        {
            "id": "13",
            "@type": [
                "geojson:Feature",
                "rte:Segment"
            ],
            "type": "Feature",
            "properties": {
                "type": "segment",
                "levelOfDetail": "visualization",
                "length_m": 282,
                "duration_s": 73,
                "roadName": "Independence Ave SW",
                "text": "Turn slightly left onto 15th St SW. Go for 282 m."
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0336866,
                    38.8877714
                ]
            }
        },
        {
            "id": "14",
            "@type": [
                "geojson:Feature",
                "rte:Destination"
            ],
            "type": "Feature",
            "properties": {
                "type": "end"
            },
            "geometry": {
                "type": "Point",
                "coordinates": [
                    -77.0352,
                    38.8897
                ]
            }
        }
    ]
}
```

Annex D: Revision History

Date	Release	Editor	Primary clauses modified	Description
2021-01-12	1.0.0-SNAPSHOT	C. Portele	all	initial version, based on Open Routing Pilot results

Annex E: Bibliography

TODO