2012

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2013-03-21
Version 1.2

[GEOREFERENCING METHODS]

A study on how to deal with georeferencing in the ROSATTE Implementation Platform

Abstract

For ROSATTE, Agora C is pointed out as a common reference system between different geographical systems and databases. OpenLR is another option. However both of these methods are originally developed for referencing traffic information to a digital road network, where limiting the amount of location descriptive data due to bandwidth is necessary. When transferring static data from a public authority to a map provider, the focus is reliability instead of bandwidth. Without constraints regarding bandwidth it is, at least theoretically, possible to extend current methods and achieve a more reliable solution.

The international standard ISO 17572 specifies two different Location Referencing Methods:

- Pre-coded Location References (Pre-coded Profile).
- Dynamic Location References (Dynamic Profile).

Linear referencing is one kind of Pre-coded Location Referencing, which is widely used for transferring static road data from one system to another. Linear referencing is the only method currently included in the INSPIRE directive.

AGORA-C and OpenLR are dynamic LRM:s. The pros with these dynamic LRM:s are the ability to overcome map differences and the flexibility. The cons are that they are less reliable than linear referencing and will probably never give a 100% hit rate and they may sometimes give the wrong result. Agora-C also has licensing fees which means extra cost for encoding and decoding and as it is an ISO-standard, it is not so easy to extend it.

Compared to AGORA-C, OpenLR is less extensive and therefore not quite as complex to implement. Furthermore, a framework of Java components is provided which can significantly reduce the effort needed to implement encoders and decoders.

Quite recently another location referencing method was developed, named Universal Location Referencing (ULR), and originating from the TPEG arena. TPEG-ULR has not been analyzed further in this study.

It is recommended to:

- Allow for OpenLR within the ROSATTE specification framework.
- Allow for linear referencing/net-matching within the ROSATTE specification framework.
- Initiate activities to improve methods for dynamic location referencing.

Recommended activities to improve methods are the following:

- Use OpenLR as a base for location referencing in relation to ROSATTE feature transfer.
- Iteratively propose, implement, test and evaluate possible extensions to the current OpenLR specification to improve the reliability of the method. This could include:
    - Analysis of typical failure situations.
    - Develop an option to include additional descriptive attributes such as road number and street name and agree on and specify a common description of the attributes used.
    - Develop an option to provide more geometric and topological information
        - Complete geometry, i.e. complete linestrings for linear geometry.
        - Information about connected road segments at junctions and about the junctions.
    - Develop rules and recommendations on how to optimize decoder and encoder processes.
- Propose, test and validate other improvements to the entire process of location transfer such as a more iterative process other and more “high-tec” aids like pattern recognition.
- Make it possible to enclose also network elements in a data exchange. Sometimes errors occur due to too large differences in the road network representations (e.g. missing elements). For this purpose it is recommended to use the INSPIRE DS TN representations of road network and linear referencing constructs within a ROSATTE dataset.

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Table 1 - Glossary and Abbreviations

Term	Definition
LRM	Location Referencing Method
DG MOVE	European Commission Directorate-General for Mobility and Transport
eMaPS	EU FP7 support action for establishing the ROSATTE Implementation Platform
INSPIRE	Infrastructure for Spatial Information in the European Community
INSPIRE DS TN	INSPIRE Data Specification for Transport Network
GDF	Geographic Data Files (ISO standard 14825)
Agora-C	ISO standard for dynamic location referencing
OpenLR	Method for location referencing, open source project launched by TomTom
TPEG-ULR	Transport Protocol Experts Group – Universal Location Referencing
TISA	Traveler Information Services Association
IPR	Intellectual Property Rights
UML	Unified Modeling Language
XML	Extensible Markup Language
GML	Geography Markup Language

1 Introduction

1.1 Prerequisites and background

For ROSATTE, Agora C is pointed out as a common reference system between different geographical systems and databases. Agora C is associated with the use of licenses and it is not certain that it will be used in the future. Trafikverket uses OpenLR and there are other organizations also finding this attractive. However both of these two location referencing methods are originally developed for referencing traffic information to a digital road network and not for transferring larger amount of more static data between different kinds of digital maps.

Limiting the amount of location descriptive data due to bandwidth is not necessary when transferring static data from a public authority to a map provider. Instead, the focus in this case is reliability, i.e giving a correct result when possible and otherwise result in an error when a location reference is impossible to interpret. Without constraints regarding bandwidth it is, at least theoretically, possible to extend current methods and achieve a more reliable solution.

The DG MOVE/Rapptrans 1.3 report and especially the recommendations in the report is a necessary base for the study. The recommendations 7 and 8 concern location referencing methods and states that AGORA-C shall be initially adopted as a map-agnostic location referencing method and that short-term improvement of OpenLR or the development of another license-free map-agnostic location referencing method shall be promoted.

1.2 Overall objective

The overall objective is to be able to transfer road data from a public authority, using one road network description, to a map maker, service providers and other actors, using another road network description, with maximum reliability.

1.3 Objectives of this study

The goal of the study is to answer the following question:

- What are the alternatives to Agora C – does it make sense to revise the ROSATTE specification with respect to new thinking around georeferencing in general, e.g. implementing OpenLR as an alternative method.
- What is the state-of-the-art regarding georeferencing?
- What support provides the DG MOVE/Rapptrans 1.3 study?
- What options are there now and in the future? Developments of existing map agnostic methods, new methods, using more detailed geometry descriptions, common linear reference systems?
- Is there a need for improvement of current georeferencing methods to fit the requirements of ROSATTE?
- Should the environment around eMaPS engage in a new complex standardization area?

By answering the above questions it should be possible to make an informed decision on how to deal with georeferencing in the first phase of the establishment of the ROSATTE Implementation Platform.

1.4 Scope and delimitations

The result of the study is this report. ROSATTE specification has not been updated in the study, although recommendations on how to update the specifications can be found in the report. No actual testing of methods or software development has been carried out in the study but the need for such testing is described.

The report does not identify the different kinds of databases that exist today at the public authority side or the possibility to use the georeferencing methods in each case.

2 Overview of location referencing methods

2.1 Introduction

The international standard ISO 17572 specifies Location Referencing Methods (LRM) that describes locations in the context of geographic databases and will be used to locate transport-related phenomena when exchanging such data between parties. The Standard defines what is meant by such objects, and describes the reference in detail, including whether or not components of the reference are mandatory or optional, and their characteristics.

The Standard specifies two different LRMs:

- Pre-coded Location References (Pre-coded Profile);
- Dynamic Location References (Dynamic Profile).

As a comparison we have also mentioned a third method called net-matching, which in reality is a two-step method, first using dynamic location referencing and then pre-coded location referencing.

2.2 Pre-coded location referencing

2.2.1 Basic characteristics

Pre-coded location referencing is a method which makes use of end-user client devices carrying a location database that is exactly the same as the corresponding location database used by a service provider of a particular message being exchanged. Generally all pre-coded location referencing methods do share the concept of defining a commonly used database of IDs.

The location referencing method here is divided into three steps performed to implement the location referencing system:

- Location data base creation and updating
- Location database provision
- Location database usage

Pre-coded location referencing methods like TMC-Location Codes are not an option here because of the lack of resolution. The only pre-coded location referencing method, described in ISO 17572, that is suitable for our purposes is linear referencing, which is described below.

In the ROSATTE data specification, pre-coded location references are named indirect location references.

2.2.2 Linear referencing

Linear referencing is widely used for transferring static road data from one system to another. Linear referencing is the only method currently included in the INSPIRE directive. Because of the reliance on predefined identifiers linear referencing is categorized as pre-coded LRM even if parts of the reference e.g. a given offset do vary inside of different references.

A linear (1-dimensional) referencing method is a method of identifying a location on a network or part of a network by reference to known positions of linear spatial objects. If space is constrained to the roadway network itself, distances along roads from established nodes (or even topologically non-significant points) can be used to specify location. Mile point or reference point sub-methods use a road label and distance measure, and mile marker, reference marker and addressing sub-methods use physical features inserted into the digital base map.

If the origin (e.g. a public authority) and the destination (e.g. a map provider) have a common understanding of a linear referencing system, this LRM could be a good alternative when transferring data between them. Linear referencing is a reliable location referencing method and is standardized in ISO 19148 – Geographic Information – Location Based Services – Linear Referencing.

2.2.3 Pros and cons

Pros:

- Very reliable, although see Cons below

Cons:

- Inflexible
- A common definition very seldom exists between different parties, and the creation of a common linear referencing system is expensive.
- There is often no common system across countries or even within countries
- There are often inconsistencies and ambiguities after constructive changes (missing mileage posts, double mileage posts etc)

2.3 Dynamic Location Referencing

2.3.1 Basic characteristics

Dynamic Location Referencing relies on specific attributes that are mostly available in current digital map databases. These methods rely on real-time access by the software to the original or translated values of the relevant attributes from its own digital map. These LRMs is also called “on-the-fly referencing” or “map agnostic location referencing” because the location reference code can be immediately discarded after internal definition of the location has been decoded. The dynamic location referencing concept is designed to compensate for differences that may exist between the map used at the sending system (the encoding side) and the map on board of the receiving system (the decoding side). Such map differences can be caused by the receiving system using an older map of the same supplier, or vice versa, or the receiving system using a map from a different supplier. Also there may be differences in how different situations have been generalized in different maps.

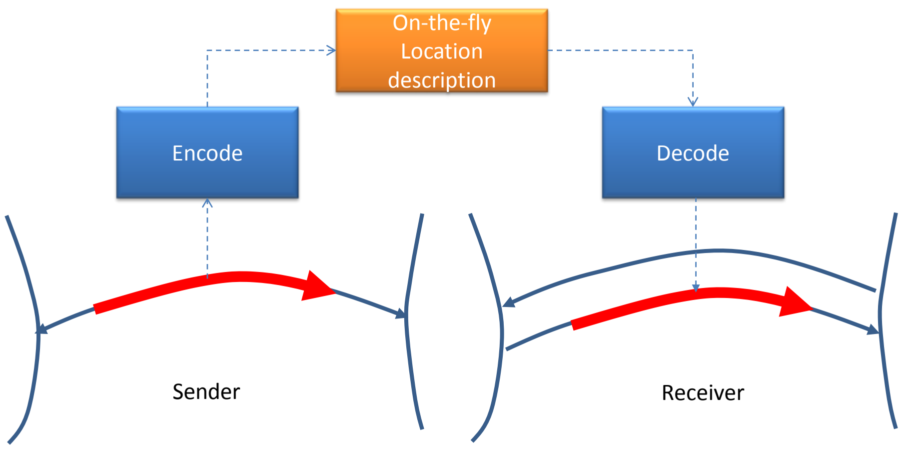

Figure 1 - Illustration of dynamic LRM

The figure above illustrates the principles of a dynamic LRM where the red arrow represents some information that needs to be passed from sender to receiver. The sender encodes the location according from the local digital map to an agreed format and passes it to the receiver who decodes the information and applies the location to the local map at the receiver side. Ideally, this works even if there are differences in the maps. This is illustrated above by the sender having one road element and the receiver having two road elements representing the same physical road.

In the ROSATTE data specification, pre-coded location references are named direct location references.

2.3.2 Agora-C

AGORA-C is a dynamic LRM that uses the following data in its location descriptions:

- Geometry. The geometry is simplified similarly to a Douglas-Peuker algorithm down to a certain deviation threshold (perpendicular distance between original and encoded geometry)
- Topology. In certain cases, information (such as bearing, accessible for routing and intersection type) regarding connected road elements at intersections/junctions is provided
- Road signature (name/number)
- Form of way (classification regarding the physical properties of the road). Originally defined in ISO 14825 – GDF
- Functional road class (classification regarding the importance of the road within the network). Originally defined in ISO 14825 – GDF
- Traffic flow direction

AGORA-C is rather extensive and therefore also quite complex to implement. The reliability depends primarily on the availability and compliance of the necessary data at either side. The implementation of encoder and decoder may also be a factor, and bilateral agreements may be necessary to achieve the best possible result. The information passed as a location reference may comply more or less between sender and receiver. The location of road elements and junctions may differ due to different rules for generalization or different measurement methods. Functional road class is not particularly clear when it comes to how it shall be used. Because of this, an AGORA decoder needs some flexibility when matching a location to the local digital map. Too rigid decoder will result in too few hits and too flexible decoder will result in hitting the wrong thing.

As AGORA-C is an ISO standard, revision or extension of the specification follows ISO formalism which is not a particularly agile process. Furthermore, the patents surrounding the specification make revision quite unclear.

As a way to facilitate open access to AGORA-C essential patents, the creators of the AGORA-C standard, Panasonic Corporation, Robert Bosch GmbH, Siemens Aktiengesellschaft and Tele Atlas BV, have come together to pool their essential patents under a single joint patent license agreement handled by Via Licensing Corporation (http://www.vialicensing.com). There are licensing fees associated with encoding locations according to AGORA-C and the licensing fees are listed in http://www.vialicensing.com/licensing/agorac-fees.aspx.

Pros and cons

Pros:

- Possible to overcome map differences
- Flexible
- Standardized

Cons:

- Less reliable than linear referencing
  - Will probably never give a 100% hit rate
  - May sometimes give the wrong result. It may be difficult to detect such errors
- Licensing fees means extra cost for encoding and decoding.
- Not easy to extend as it is an ISO-standard and patents make a process for revision complicated.
- Quite complex to implement.

2.3.3 OpenLR

OpenLR is a dynamic LRM that uses the following data in its location descriptions:

- Geometry. Ideally, the geometry contains only the points (which are nodes in the network graph) needed to ensure that a shortest path calculation via the selected points describes the desired location. A number of attributes derived from geometry are also provided, such as lengths and bearings.

- Topology. The selected points shall primarily represent nodes (junctions) in the network. No information is provided regarding connected road elements (that are not part of the location itself).
- Form of way (classification regarding the physical properties of the road). Originally defined in ISO 14825 – GDF
- Functional road class (classification regarding the importance of the road within the network). Originally defined in ISO 14825 – GDF

Compared to AGORA-C, OpenLR is less extensive and therefore not quite as complex to implement. Furthermore, a framework of Java components is provided which can significantly reduce the effort needed to implement encoders and decoders.

The same way as for AGORA-C, the reliability depends primarily on the compliance of the necessary data at either side. The implementation of encoder and decoder may also be a factor, and bilateral agreements may be necessary to achieve the best possible result. An extension to Open LR aims to decrease the need for bilateral agreements, to be able to use a more general decoder at a ROSATTE Implementation Platform. The information passed as a location reference may comply more or less between sender and receiver. The location of road elements and junctions may differ due to different rules for generalization or different measurement methods. Functional road class is not particularly clear when it comes to how it shall be used. Because of this, an OpenLR decoder needs some flexibility when matching a location to the local digital map. Too rigid decoder will result in too few hits and too flexible decoder will result in hitting the wrong thing. Compared to AGORA, OpenLR location references consists of less information (no road signature and no side road information) which might lead to results that are inferior compared with AGORA-C. However, we have not found any evidence for this.

OpenLR is an open source project launched by TomTom International B.V. Therefore, one can assume that there is less formalism (compared with ISO) involved in revising or extending the specification.

OpenLR is royalty free which is an advantage compared to AGORA-C.

Pros and cons

Pros:

- Possible to overcome map differences.
- Flexible.
- Open source and royalty free, i.e. no extra cost for encoding and decoding.
- Relatively easy to extend as it is open source, though certain extensions may collide with AGORA-pool patents.
- Relatively easy to implement.

Cons:

- Reliability similar to AGORA-C
  - Will probably never give a 100% hit rate.
  - May sometimes give the wrong result. It may be difficult to discover such errors.

2.3.4 TPEG-ULR

Quite recently another location referencing method was developed, named Universal Location Referencing (ULR), originating from the TPEG arena. TPEG-ULR introduces an innovative approach for dynamic location referencing based on Markov chains, but also supports mapless-client-applications. Development of TPEG-ULR was motivated both by technical considerations and commercial issues with other location referencing methods. TPEG-ULR is especially suitable for public digital broadcasting applications such as DAB(+). After further optimization, it is planned to publish a reference implementation of the ULR algorithm under an open-source license and submit the finalized ULR algorithm to TISA standardization. More information can be found at http://publica.fraunhofer.de/documents/N-192560.html

This new method has not been tested within the ROSATTE project. We have no information on how the method performs compared to AGORA or OpenLR and we have therefore not at this stage made any deeper investigation of the method. We still would like to mention the method as something that could be a future alternative also for ROSATTE.

2.4 Net-matching

Net-matching is a method that was used in EuroRoads, introduced by PTV. The first step in net-matching is to compare the road network from the sender with the road network from the receiver and establish a common interpretation between the two networks. Tables with common reference ID:s will make it possible to use linear referencing in the next step which is the actual exchange of attributes.

This way, net-matching is kind of a combination of dynamic and pre-coded location referencing. The process might even include manual steps in order to accomplish a perfect mapping between the networks/maps. During the writing of this report we have not, due to time restrictions, been able to investigate the details, pros and cons of this method. Even so, we would like to add it to the list of georeferencing methods worth further investigation.

2.5 A comparison between different methods

The different referencing methods can be rated according to some evaluation criteria's. 1 is very bad and 5 is very good in the table below. The ratings below reflect the opinion of the authors of this report and are not to be considered as absolute truth.

Evaluation criteria	***Linear referencing****	**Agora-C**	**OpenLR**
Reliability	*5*	3**	3**
Flexibility	*1*	4	4
Easiness to extend	*2*	3	4
Easiness to implement	*4*	2	3
Licensing and cost of use	*4*	2	4
Overall	***16***	**14**	**18**

* Linear referencing is not an option when the sender and the receiver have different road network descriptions. Linear referencing exists in the table only as a reference to the other methods.

**An extension to either Agora-C or OpenLR will have as an important goal to result in better reliability, but otherwise with the same rating as the original methods.

A definition and explanation of each evaluation criteria can be found on the table below.

Evaluation criteria	**Definition/explanation**
Reliability	The chance of getting a correct result when transferring data from sender to receiver using the method. A more detailed definition can be found in 4.1 below.
Flexibility	The possibility to use the method independently of network and data at sender and receiver side.
Easiness to extend	Is it possible for the ROSATTE environment to extend the method without delays, methods standardized by ISO will result in delays.
Easiness to implement	An unambiguous specification is a basic prerequisite for implementing a method. When examples and ready-to-use-code exist (as for OpenLR in Java) implementing the method will be much easier.
Licensing and cost	Licensing associated with cost will be an obstacle for spreading

of use	implementation and use of a method.

3 Use of pre coded LRM:s

3.1 Linear Referencing

It is not very common that linear referencing systems (LRS) that are shared between several parties exist. However, there are cases, for example in Sweden and Norway, where a national road database (NVDB) founded nationwide LRS:s which are being used as means for location referencing.

If shared linear referencing systems (LRS) do exist, it is the preferred LRM primarily due to the reliability aspect. The current ROSATTE specifications do not explicitly include LRS as a valid option, although the schemas contain an abstract base definition (class) allowing pre coded LRM (such as LRS) to be easily added without affecting the existing schemas. An LRS definition in ROSATTE should use suitable parts of the ISO 19148 standard, of which the INSPIRE model is a small subset.

3.2 Other pre coded LRM:s

Other types of pre coded LRM:s identified in ISO 17572, such as location code, does not have enough resolution to fulfill the needs of ROSATTE.

4 Use of dynamic LRM:s

4.1 Overview

If common linear referencing systems (LRS) do not exist, a dynamic LRM will be used. Agora-C is included in the ROSATTE specification, but it is no big effort to also insert OpenLR or extended versions of Agora-C or OpenLR.

As already explained, dynamic referencing methods do have some drawbacks, which are exemplified and described below as well as suggestions on how to overcome these problems.

To be able to discuss success or failure when transferring locations we must define what a successful location transfer is.

For the transfer of static and temporary road data, we have identified reliability as the most important requirement. We define reliability in this sense as two things:

- If there is a theoretical non-ambiguous mapping between a location in the senders map and a corresponding location in the receivers map, a location transfer should succeed. See below for a definition of a successful location reference transfer.
- If there is no non-ambiguous mapping between a location in the senders map and a corresponding location in the receivers map, a location transfer should fail giving the parties an opportunity to take necessary actions to make the maps compliant. The ability to detect errors is also considered a success, since it gives the users a chance to make things right instead of “sweeping the problem under the carpet”

Regarding successful location reference transfer, the ROSATTE report D5.4 makes the following definitions (where LA means Local Authority, i.e. sender and MP means map provider, i.e. receiver) :

Quality parameter	Definition for testing and validation
Topological correctness	Integration result needs to (1) Follow same route as original (2) Have the same direction as original (3) Start- and endpoints need to lie on the topological correct link (does not matter where exactly on that link)

Geometric accuracy	(1) Identify reference location in receiver map - At intersections: same distance from intersection point to location point in both maps - Apart from intersections: project original point on LA map onto MP map (2) Measure distance between reference location and integration result in MP map (3) Distance is to be judged according to application requirements

In the same document, the following success criteria have been defined:

Quality parameter	Entry level	1* Information application	2* Warning application	3* Control application
Topological correctness	>80%	>90%	>95%	>99%
Geometric accuracy	50 m	20 m	10 m	5 m

4.2 Examples of failing data transfers

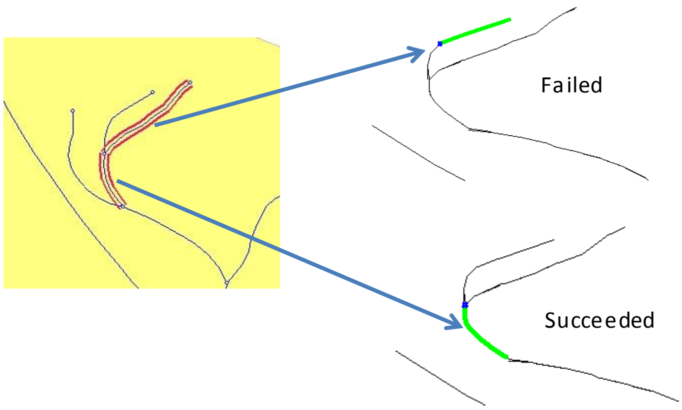

Figure 2 – Topologically incorrect result

The figure above shows an example where an OpenLR location failed to decode properly. The two parallel road links at the north end of the network (after the branch) have similar properties and there is no obvious way (without adding more information) to automatically detect this error. If there were more information that helps to distinguish the two road elements from each other (other than geometry, which obviously doesn't suffice in this case), the problem could be solved.

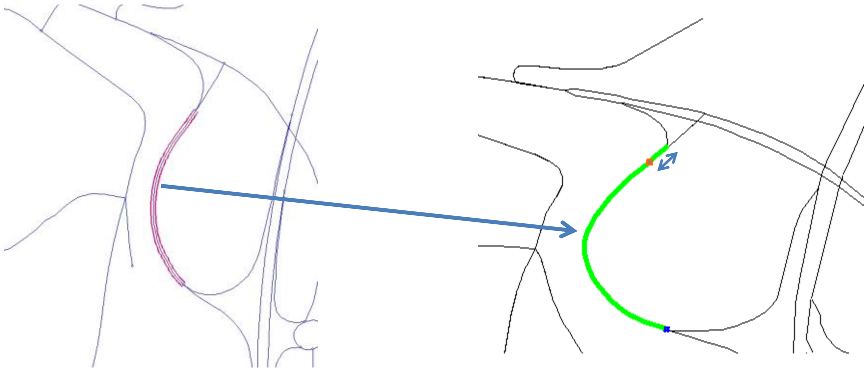

Figure 3 – Geometrically incorrect result

According to the above definitions, this example shows a geometric inaccuracy. However, the result may be due to decisions made in the decoder where geometry seems to have a higher priority than topology. Maybe the end point (red dot) is the most correct point from a geometric viewpoint, but from a topological viewpoint, the intention is to describe a location that starts and ends at the junctions.

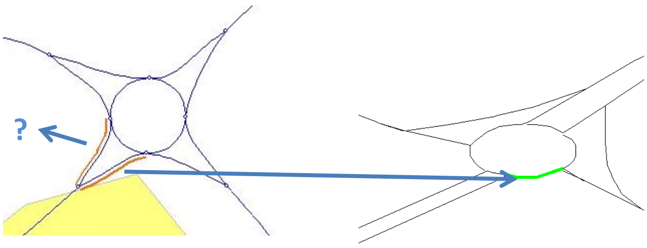

Figure 4 - Different representations of the same physical network

In this case, the networks have been generalized differently. Perhaps the two locations from the sender should have been mapped to parts of the two road elements connected to the roundabout in the receiver map or not mapped at all (i.e. resulted in an error).

The ROSATTE report D5.4 has a number of similar examples in chapter 2.5.2.

4.3 Summary of problem areas

4.3.1 Deviations in attribute descriptions

E.g. different classification of functional road class.

4.3.2 Topological deviations

E.g. one node in one map and two nodes in the other map or one link in one map and two parallel links in the other map.

4.3.3 Geometrical deviations

Very different geometrical description

4.3.4 Implementation of encoder and decoder software

As mentioned before, a decoder needs to be tuned, possibly for each encoder. There is the possibility to develop better or worse decoders for each case. Each encoder and decoder pair needs to be tested and tuned to perform as good as possible.

4.4 Actions to overcome the problem areas

4.4.1 Common basic description of attributes

If the definitions of attributes are sufficiently precise, there is a greater chance that the sender and receiver data will comply. This also means that the decoder may be implemented in a more restrictive fashion and still result in a high hit rate (without hitting the wrong locations).

One concrete example is functional road class which leaves a lot of room for interpretation, which in turn leads to discrepancies between parties. In ROSATTE, a more restrictive definition of functional road class was used:

- FC 0: motorway, freeway (flow road)
- FC 1: major road for motor vehicles not a motorway (through road)
- FC 2: arterial road (both long distance and local)
- FC 3: local distributor/collector road
- FC 4: local road

Another example is to have a common understanding of how to handle road numbers and street names.

4.4.2 A more extensive topological description

Due to the aim of minimizing bandwidth in the current methods, the topological description is also minimized especially in OpenLR. A more extensive topological description is not a problem in the context of ROSATTE and it will probably enhance the result. Some road networks use different levels in the description of the network. This might result in worse results. Therefore it is important to agree on which level to use (i.e. carriageway).

Perhaps it is not possible to standardize how to describe the topology of a road network, but a dialogue among all stakeholders regarding topological descriptions is welcome.

The best possible topological matching between networks will improve the results. To study alternative methods for topological matching might give valuable input to be able to develop methods with better performance than the ones used today. Methods for topological matching also exist outside the field of transportation and mapping.

4.4.3 More detailed geometrical description

A fully geometrical description could help getting better reliability in the matching. Again, bandwidth is not the main concern in the context of ROSATTE.

4.4.4 Adding attributes describing the underlying network

All attributes that help identifying correct road segments should be used.

As an example, OpenLR doesn't use road numbers and street names. Adding these attributes will probably improve the reliability of the matching when other attributes does not suffice.

4.4.5 Use a complete network description

If we extrapolate the above to the full extent, we are actually transferring all information about the parts of the road network that is needed to describe the desired location and that exists at the provider side. Within the INSPIRE data specification for road networks, road network geometry and topology can be represented together with a number of attributes such as form of way, functional road class, road name and road number. If bandwidth is not an issue in the context of ROSATTE it would be possible to use the INSPIRE network representation to a complete enough extent to describe the location for the various ROSATTE data elements. Since INSPIRE is European law that shall be implemented by all member states, it should also be safe to use from an IPR perspective.

4.4.6 Develop an iterative process

As the exchange of static road data is not a time critical process, it would be possible to implement an iterative process where the sender and the receiver exchanges data with each other in several steps. The receiver could send back uncertain matching results, if these may be identified, and ask the sender for verifications. An iterative process cannot be mandatory, since some receivers and providers may not be in a position to provide structured feedback (e.g. community sourced maps).

4.4.7 Other possible actions

These actions should also be evaluated:

- Develop a process on how to adjust and tune each decoder towards each encoder.
- Agree on decoding rules such as how to prioritize the topology vs. geometry and the other attributes.
- Use of aerial photos like Google earth and pattern recognition to identify correct road segments. (Current Google photos are too old for using in this context).

5 Recommendations

5.1 Introduction

The recommendations below concern activities needed within the ROSATTE framework to meet the recommendations from the DG MOVE/Rapptrans 1.3 report concerning location referencing methods:

- "Initially adopt AGORA-C as map-agnostic location referencing method"
- "promote short-term improvement of OpenLR or the development of another license-free map-agnostic location referencing method as alternative to AGORA-C"

Since AGORA-C is already supported within the ROSATTE framework, no additional activity is proposed to satisfy the "Initially adopt AGORA-C…" recommendation.

5.2 Allow for OpenLR within the ROSATTE specification framework

To be able to use OpenLR as an alternative and valid method for map-agnostic location referencing, the ROSATTE specifications need to be extended to include this option. A concrete proposal for extending the ROSATTE specifications to include OpenLR is provided in chapter 6 in this document.

5.3 Initiate activities to improve methods for dynamic location referencing

5.3.1 Background

Extending or developing methods for dynamic location referencing to improve the results is not a simple task. This study points out that there are areas where the existing methods could be improved considering the fact that bandwidth is not the primary concern in the context of ROSATTE.

To improve the existing methods and tools one needs to:

- Identify the typical problem areas
- Select test datasets with a representative distribution of the data and also locations which includes the various problem areas
- Specify the necessary extensions to the existing methods and tools to resolve the problem areas
- Implement the extensions in the encoders and decoders
- Perform tests and verification that the extensions had the desired effect without any other negative side effects
    - Create a testing environment where encoding/decoding of large samples can be rapidly tested

It is our belief that OpenLR, in the short term, should be the preferred platform for such test and validation. The reason for this is primarily that the licensing and patent situation is simpler than for AGORA-C. Also, we believe that extensions to the specifications may be easier for OpenLR due to a more agile process. However, it should be noted that such extensions may intrude on existing AGORA patents, therefore we recommend contact with the Agora-C licensing organization before extending OpenLR. On the other hand extrapolate the use of extended geometry and topology to the full extent, i.e. transferring all information about the relevant road segment, should not intrude on any pattern, as it is included in the INSPIRE-specification.

An alternative to OpenLR could be TPEG-ULR. This requires several parties, both authorities and map providers, to be involved in the development and testing of the method. Since also TPEG-ULR aims to be open, it might be possible for parties within the ROSATTE community to join and at a later stage include the method as a valid option for ROSATTE. Since the terms for such a commitment is not clear to the authors of this report at this stage, such a decision is not included in the report.

In longer term, it could be investigated if the development of totally new methods dedicated for transferring static data, could be promoted

5.3.2 Recommendation

Initiate an activity with the goal to achieve a good enough location referencing method for ROSATTE purposes based on OpenLR. The reports from ROSATTE WP5 (D5.*) should be used as reference for this activity, since they include both a methodology and the requirements for testing and validation, i.e. a definition of what is “good enough”. This activity should use OpenLR as basis and has to involve several parties. Ideally, a process similar to the ROSATTE test phase is preferred, with two data consumers (decoders) and more than two data producers (encoders).

The activity should involve the following:

- To use OpenLR as a base for location referencing in relation to ROSATTE feature transfer between public authorities and map makers/others. This requires the 5.2 recommendation to be implemented. A proposal for this is provided in chapter 6 below.
- Iteratively propose, implement, test and evaluate possible extensions to the current OpenLR specification to improve the reliability of the method in the context of ROSATTE. This could include:
  - Analysis of typical failure situations
  - Develop an option to include additional descriptive attributes such as road number and street name.
    - Agree on and specify a common description of the attributes used. This increases the chance of supplier and consumer interpreting a real world situation the same way leading to improved results. Example of this is functional road class where the definition could be made clearer.
  - Develop an option to provide more geometric and topological information
    - Complete geometry, i.e. complete linestrings for linear geometry.
    - Information about connected road segments at junctions and also information about the junctions (i.e. if they represent a junction, road end, roundabout, pseudonode etc)
  - If necessary, develop rules and recommendations on how to optimize decoder and encoder processes. Prioritize, adjust depending on attributes and quality in sender- and receiver maps, tolerances etc.
- Propose, test and validate other improvements to the entire process of location transfer. This could include:
  - A more iterative process as discussed earlier

- Other, more “high-tec” aids like pattern recognition
- Use complete INSPIRE DS TN network to describe locations relative to the road network. This could involve inclusion of INSPIRE network elements and linear referencing constructs within a ROSATTE dataset.
    - This method would involve ROSATTE safety features directly referencing network elements (including all available INSPIRE attribution) which are included (or somehow accessible) in or from the same dataset

5.4 Allow for linear referencing within the ROSATTE specification framework

If there, between parties, is a possibility to use linear referencing, this option should be allowed and recommended within the ROSATTE specifications. This is also to be viewed as an alignment with the INSPIRE DS TN specification. This is perhaps not directly in accordance with the DG MOVE/Rapptrans 1.3 report recommendations, but the cost (for extending the ROSATTE specifications) is small and the potential benefit is large if the proper preconditions exist (common linear referencing system or existing method for net-matching). A concrete proposal for extending the ROSATTE specifications to include linear referencing is provided in chapter 6 in this document.

5.5 Longer term: develop or promote another license-free method for dynamic location referencing

The development of TPEG-ULR should be investigated and perhaps promoted and tested when possible. It is hard to judge at the moment if TPEG-ULR or something else is the “silver bullet” method for location referencing. Ideally, the method for ROSATTE should from the start be developed and optimized for transferring static road data from one road network to another, and not extensions to methods originally designed for referencing dynamic traffic information to a road network.

The fact that no “silver bullet” method for dynamic location referencing exists despite the fact that such needs have existed for many years may indicate that the development of such a method is not a simple task. The effort for such development is probably not negligible and the payback is very unsecure. Furthermore, before results from a test with extending OpenLR has been evaluated, it is impossible to know if there is a need for another method at all.

Therefore, the recommendation from this report is to focus the short term efforts on improving the existing methods for dynamic location referencing (e.g. OpenLR) to try meeting the needs and requirements for ROSATTE.

6 Implementation in the ROSATTE specification

6.1 Introduction

To allow for the recommendations above, there is a need for a couple of minor additions to the ROSATTE specifications:

- Add OpenLR as an option.
- Allow for linear referencing when “net-matching” has been done as a first step.

The ROSATTE specifications are quite open to these kinds of extension. The basic model for ROSATTE feature transfer is shown in the figure below:

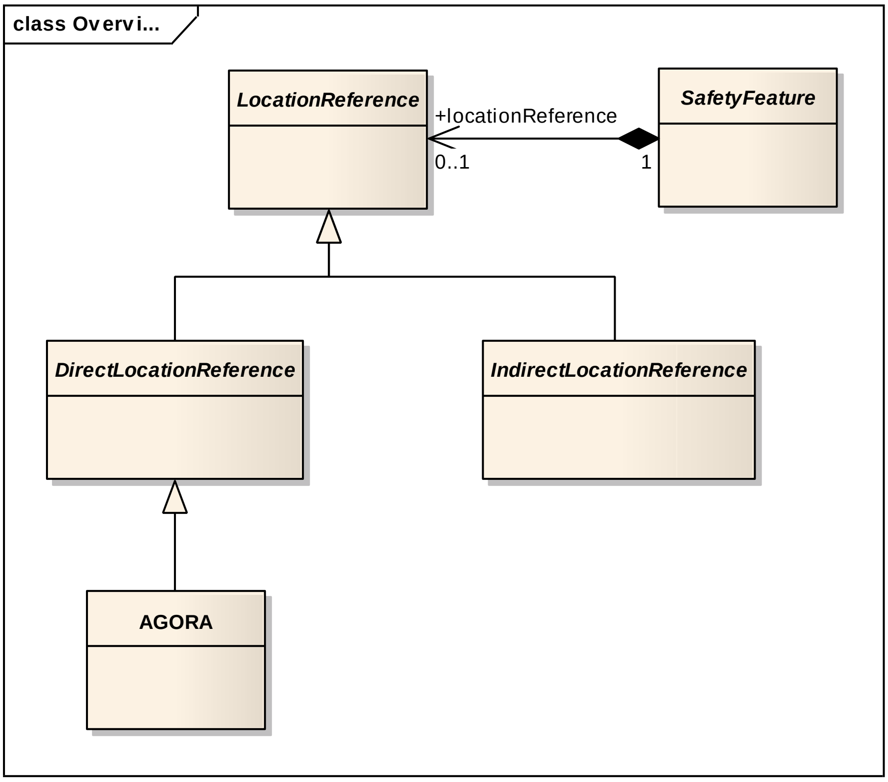

Figure 5 - Basic ROSATTE schema

This means that any SafetyFeature (the basic concept for information transfer within ROSATTE) may have a location reference which may be either direct (such as AGORA) or indirect (such as a linear reference). This structure is abstract and the only concrete location referencing option as of today is to use AGORA.

The data structures of ROSATTE are defined on a conceptual level in an application schema (UML) and on a concrete physical format level in the form of xsd-files (XML-schemas according to GML). Both the abstract application schemas and the xsd files need to be updated. Both of these reside in the ROSATTE D3.1 deliverable (specification of data exchange methods).

6.2 Application schema update

The application schema for ROSATTE is defined in D3.1, chapter 6 and in particular it is the package location referencing (Chapter 6.4) that needs update. Without affecting any existing part of the model, both linear referencing and OpenLR may be added easily. In the figure below both OpenLR and the NetworkReference (basis for linear referencing) class of INSPIRE has been added as options.

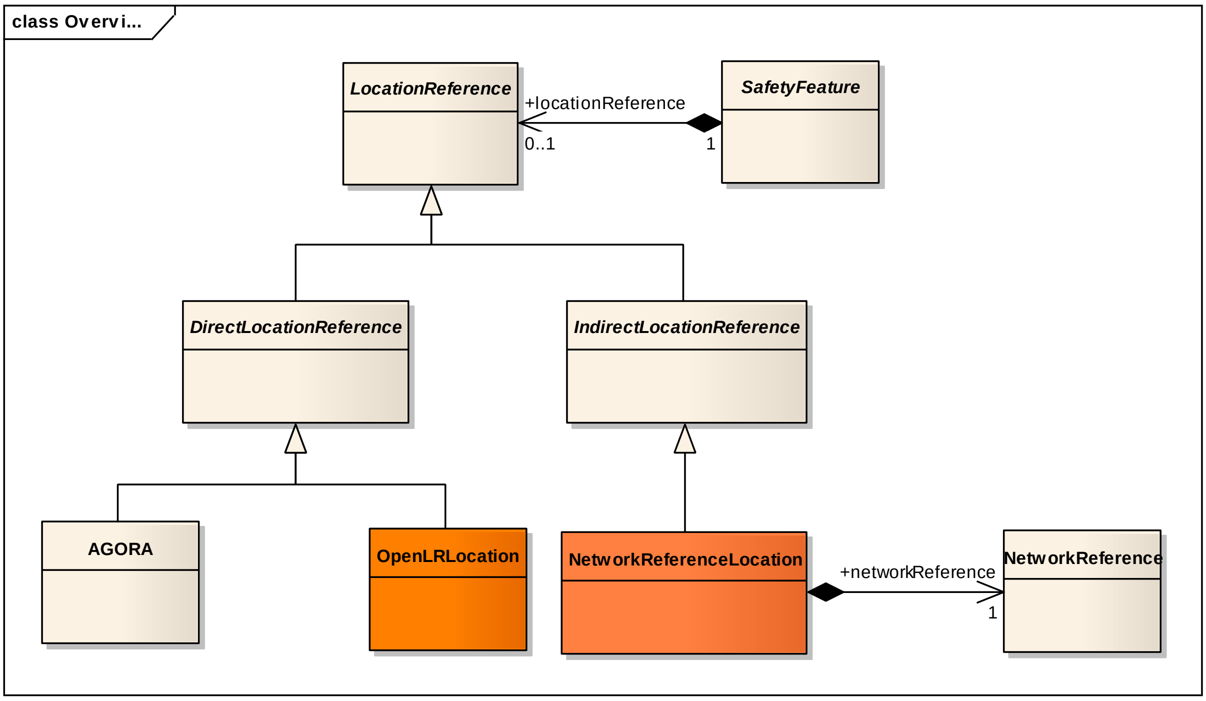

Figure 6 - ROSATTE schema with OpenLR and NetworkReference

6.2.1 OpenLR

Adding OpenLR to the application schema (at the conceptual level) only requires specifying the OpenLRLocation class as a specific subtype to DirectLocationReference. The technical details of this must be handled in the xml schema part.

6.2.2 Linear Referencing

The NetworkReference structure for INSPIRE allows for both references to arbitrary elements in the network or subsets (infinitely small such as points or larger linear intervals) of linear elements. The linear referencing model refers to the model for the network itself (see figure below). Since ROSATTE specifies no explicit road network model of its own, it should be ok to just refer to the INSPIRE model since it is a publicly available specification. The figure below shows the specifics for the location referencing (including linear referencing) of INSPIRE.

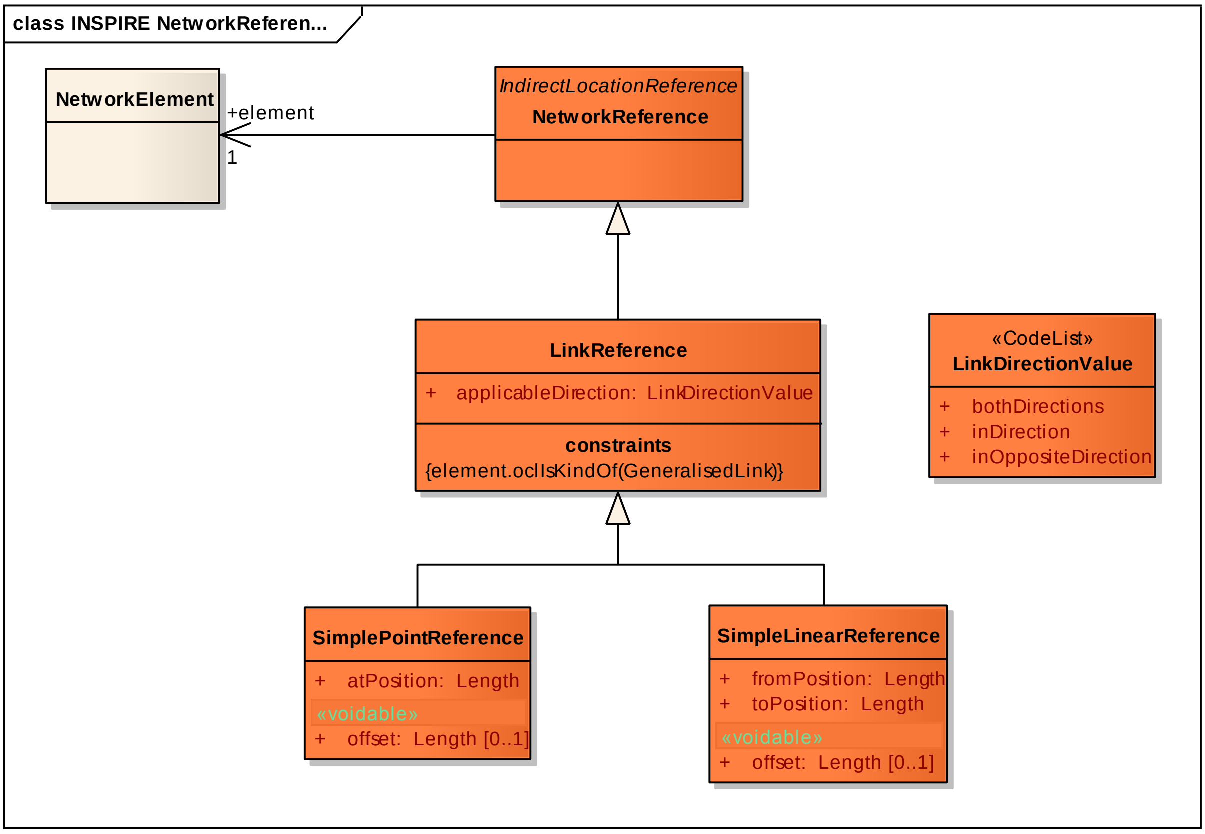

Figure 7 - Location referencing (and linear referencing) according to INSPIRE

NetworkElement is the INSPIRE base class for elements in a network. This class is a base class for concepts such as links and nodes (typical network constructs and analogue to road elements and junctions within GDF).

NetworkReference is the base class for locating other data on the network. This is a concrete class that allows for connecting data to any type of network element (such as link or node). SimplePointReference and SimpleLinearReference are used to specify point or linear locations (similarly to AGORA/OpenLR) by specifying a linear element and lengths along that element.

In the context of ROSATTE, no case where the network itself is transferred between parties has been identified. Even if the model for linear referencing is defined as above (with a reference to NetworkElement), no network element data needs to be transferred in an xml encoding since XLink mechanisms (perhaps instantiating the reference as a URN) may be used.

6.3 XML schema update

6.3.1 OpenLR

As seen above, making the necessary application schema changes for ROSATTE is pretty easy. In a similar fashion, the xml schemas for ROSATTE are structured accordingly.

This means that a definition corresponding to the OpenLRLocation class in the application schema may be added to the xsd (in the DirectLocationReference substitutionGroup):

```
<element name="OpenLRLocation" type="rst:OpenLRLocationType" abstract="false"
substitutionGroup="rst:DirectLocationReference"/>
<complexType name="OpenLRLocationType" abstract="false">
    <complexContent>
        <extension base="rst:DirectLocationReferenceType">
            <sequence>
                <element ref="openlr:OpenLR"/>
            </sequence>
        </extension>
    </complexContent>
```

```
</complexType>
```

The element openlr:OpenLR is a global element defined in the OpenLR xsd that contains options for both a base64 (“stringified”) binary encoding and an xml encoding. Adding this element to the ROSATTE xsd (in addition to the necessary OpenLR schema import) opens up for the use of OpenLR for ROSATTE.

6.3.2 Linear referencing

Since the xml schemas for NetworkReference already exists within INSPIRE and are publicly available) we only need to add a class that connects NetworkReference to the ROSATTE structure (in the IndirectLocationReference substitutionGroup) to be able to use it as a kind of location reference for a ROSATTE safety feature. This may be done in the following way:

```
<element name="NetworkReferenceLocation" type="rst:NetworkReferenceLocationType" abstract="false"
substitutionGroup="rst:IndirectLocationReference"/>
<complexType name="NetworkReferenceLocationType" abstract="false">
    <complexContent>
        <extension base="rst:IndirectLocationReferenceType">
            <sequence>
                <element name=”networkReference” type="net:NetworkReferencePropertyType "/>
            </sequence>
        </extension>
    </complexContent>
</complexType>
```

Of course the INSPIRE schema (Network.xsd) has to be imported as well. As stated before, the NetworkReferencePropertyType allows links (XLink) to the referenced elements in the network allowing for datasets where the network itself does not have to be enclosed in the dataset.

7 Alignment with INSPIRE

Currently, linear referencing is the only option for location referencing in the INSPIRE specification. Extending the specification with dynamic referencing is possible. How this may be done will be elaborated in another study.

8 Standardization

As OpenLR is provided under the terms of the Creative Commons Public License, standardization within ISO is probably not the intention for the organization behind OpenLR (TomTom).

ISO TC204 will probably be the accurate forum for standardization of the suggested dynamic location referencing method. ISO 17572 part3, established 2006-11-20, equals dynamic location referencing with Agora-C as it was the only method available at that time. An upcoming standardization work would need to widen this definition.

References

8.1 Input from people

People	Organization
Olle Bergman	TrV
Trond Hovland	NPRA

8.2 Documents and websites

Reference	Date
ISO_LRM_17572_Part1, ISO_LRM_17572_Part2, ISO_LRM_17572_Part3	2006-11-20
ISO 19148 – Geographic Information – Location Based Services – Linear Referencing	2011-10
OpenLR – http://www.openlr.org	2012-04
INSPIRE - http://inspire.jrc.ec.europa.eu/	2012-09
ROSATTE - http://www.ertico.com/rosatte	2012-09
Thilo Ernst, Matthias Schmidt, Andreas Schramm: TPEG-ULR: A new Approach for Dynamic Location Referencing, ITS WC Vienna	2012-10
Kees Wevers: Map-based location referencing: status and prospects, ITS WC Vienna	2012-10