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Foreword

This final draft European Standard (EN) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS), and is now submitted for the Vote phase of the ETSI standards EN Approval Procedure.

The present document is part 2 of a multi-part deliverable covering Facilities Layer function, as identified below:

Part 1: "Services Announcement (SA) specification";

Part 2: "Position and Time management (PoTi); Release 2".

The present document is based on inputs provided by various European projects including AutoNet, Concorda, Ensemble, Hights, PRoPART, Dutch-Germany-Austria Corridor, Scope@F, A58 (NL), PRE-DRIVE C2X, DRIVE C2X, SafeSpot, CVIS, CoVeL, SCOR@F, simTD, etc.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
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Modal verbs terminology

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

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Introduction

Intelligent Transportation Systems Cooperative, Connected and Automated Mobility (CCAM) related use cases in the ITS environment as specified in the ETSI ITS architecture (ETSI EN 302 665 [i.1]) can be distributed over multiple ITS stations (ITS-Ss). ITS-Ss interact in the ITS system to exchange sensor data and traffic related information to make each other aware of traffic safety or traffic efficiency circumstances and situations by which each ITS-S equipped road user, whether automated or not, can improve their safety and efficiency related decisions.

1 Scope

The present document provides the specification of the Position and Time (PoTi) services. It includes functional and operational requirements for the position and time data to support ITS Applications. In addition, it includes the definition of syntax and semantics of messages exchanged between ITS Stations (ITS-Ss) to augment the position and time accuracy. Finally, it specifies the facilities layer protocol in support of such message exchanges.

2 References

2.1 Normative references

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

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

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

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

[1] ETSI TS 103 301: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[2] RTCM 10402.3: "Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service".

[3] RTCM 10403.3: "Differential GNSS (Global Navigation Satellite Systems) Services - Version 3".

[4] ETSI EN 302 663 (V1.3.1) (01-2020): "Intelligent Transport Systems (ITS); ITS-G5 Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[5] ETSI EN 302 890-1 (V1.2.1) (07-2019): "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification".

[6] World Geodetic System 1984 (WGS84).

NOTE: Available at http://earth-info.nga.mil/GandG/update/index.php?dir=wgs84&action=wgs84#tab_wgs84-res.

[7] ISO 8855 (2011): "Road Vehicles -- Vehicle dynamics and road-holding ability -- Vocabulary".

[8] ETSI TS 103 248: "Intelligent Transport Systems (ITS); GeoNetworking; Port Numbers for the Basic Transport Protocol (BTP)".

[9] ISO 5725-1 (1994): "Accuracy (trueness and precision) of measurement methods and results -- Part 1: General principles and definitions".

[10] ETSI TS 102 894-2: "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[11] ETSI EN 302 931 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Geographical Area Definition".

[12] ISO/TS 16460:2016: "Intelligent transport systems -- Communications access for land mobiles (CALM) -- Communication protocol messages for global usage".

[13] Recommendation ITU-T X.691/ISO/IEC 8825-2:2015: "Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)".

2.2 Informative references

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

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

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

[i.1] ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture".

[i.2] ETSI TR 102 638 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions".

[i.3] ETSI EN 302 637-2: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.4] ETSI EN 302 637-3: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[i.5] ETSI TS 102 894-1 (V1.1.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 1: Facility layer structure, functional requirements and specifications".

[i.6] ETSI TR 103 299: "Intelligent Transport System (ITS); Cooperative Adaptive Cruise Control (CACC); Pre-standardization study".

[i.7] ETSI TS 103 324: "Intelligent Transport Systems (ITS); Cooperative Perception Services".

[i.8] ETSI TS 103 246-1 (V1.2.1) (03-2017): "Satellite Earth Stations and Systems (SES); GNSS based location systems; Part 1: Functional requirements".

[i.9] EUREF: European Terrestrial Reference System 89 (ETRS89).

NOTE: Available at http://etrs89.ensg.ign.fr.

[i.10] ETSI TR 101 607 (V1.1.1) (05-2013): "Intelligent Transport Systems (ITS); Cooperative ITS (C-ITS); Release 1".

[i.11] ISO 3534-1 (10-2009): "Statistics - Vocabulary and symbols - Part 1: General statistical terms and terms".

[i.12] ETSI TS 136 305 (V11.2.0): "LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN (3GPP TS 36.305 version 11.2.0 Release 11)".

[i.13] IETF RFC 5905 (June 2010): "Network Time Protocol Version 4: Protocol and Algorithms Specification".

[i.14] IEC 60050: "International Electrotechnical Vocabulary", 113-01-08 (instant), 113-01-10 (time interval), 113-01-13 (duration).

[i.15] IS-QZSS-L6-001: "Quasi-Zenith Satellite System Interface Specification Centimeter Level Augmentation Service".

NOTE: Available at https://qzss.go.jp/en/technical/download/pdf/ps-is-qzss/is-qzss-l6-001.pdf.

[i.16] IETF RFC 8173 (June 2017): "Precision Time Protocol Version 2 (PTPv2) Management Information Base".

[i.17] EN ISO 22418: "Intelligent transport systems - Fast service announcement protocol (FSAP) for general purposes in ITS" (produced by CEN).

[i.18] IEEE™ 1609.3: "IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Networking Services".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

accuracy: closeness of a measured value to a standard or known value

heading: orientation of the horizontal velocity vector with respect to the WGS84 [6] North (clockwise), unless otherwise noted

horizontal speed: magnitude of horizontal velocity-vector of the reference position point

horizontal velocity vector: projection of the 3D velocity vector on the WGS84 [6] ellipsoid

integrity risk: probability, per unit of time, of having a Parameter Failure without issuing an alert within the Time-to-Alert

ITS constellation: group of ITS-Ss which are exchanging ITS data among themselves

ITS time: time based on TAI

NOTE: Epoch of this time is set to 2004-01-01T00:00:00Z, that is 0 seconds on 1st of January 2004 UTC.

parameter failure: failure occurring when the position and time entity is unable to estimate parameters with an error less than the maximum tolerable error (err > err_max)

position integrity: measure of the trust that can be placed in the correctness of the estimated Parameters supplied by the Position and Time entity

NOTE: Integrity includes the ability of the equipment (at the Position and Time entity and/or User level) to compute timely and valid alerts when the estimated Parameters do not need to be used for the operation of interest.

protection level: estimated bound on the Parameter Error from the Position and Time entity at a defined confidence level such as 50 %, 75 %, 95 %, 99 %, etc., delivered with the Parameters

station clock: clock representing ITS time in an ITS Station

Time-to-Alert: maximum allowable elapsed time from the onset of a Parameter Failure until the equipment annunciates the alert

velocity: vector indicating speed in a particular direction

vertical velocity vector: projection of the 3D velocity vector on the normal vector of the WGS84 [6] Ellipsoid

3.2 Symbols

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

Tsys ITS Station Time

3.3 Abbreviations

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

3D	3 Dimensional
ACC	Automatic Crouse Control
ACK	Acknowledgement
ASN	Abstract Syntax Notation
BSA	Basic Set of Applications
CA	Cooperative Awareness (service)
CACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
CCAM	Cooperative, Connected and Automated Mobility
CDD	Common Data Dictionary
CP	Collective Perception (service)
CVIS	Cooperative Vehicle-Infrastructure Systems
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
D-GNSS	Differential Global Navigation Satellite System
ECU	Electronic Control Unit
EDAS	EGNOS Data Access Service
EGNOS	European Geostationary Navigation Overlay Service
EU	European Union
FA-SAP	Facilities to Applications Service Access Point
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite Systems
GPC	GNSS Positioning Correction
GPS	Global Positioning System
GRM	GPS Raw data Message
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
ITRF	International Terrestrial Reference Frame
ITS	Intelligent Transport Systems
ITS-C	ITS Constellation
ITS-S	ITS Station
ITU-T	International Telecommunication Union - Telecommunication standardization sector
MAC	Media Access Control
NA	Not Applicable
NF-SAP	Network to Facilities Service Access Point
NGA	National Geospatial-intelligence Agency
NRTK	Network Real Time Kinematic
NTP	Network Time Protocol
PDU	Protocol Data Unit
PoTi	Position and Time
PPP	Precise Point Positioning
PSID	Provider Service Identifier
RAN	Radio Access Network
RF	Radio Frequency
RFC	Request For Comment
R-ITS-S	Roadside ITS Station
RTCM	Radio Technical Commission for Maritime services
RTCMEM	Radio Technical Commission for Maritime services Environmental Message
RTK	Real Time Kinematic
SA	Service Announcement
SAM	Service Announcement Message
SF-SAP	Security to Facilities Service Access Point
SI	Standard International
SIFS	Short InterFrame Space
SLR	Satellite Laser Ranging
SPATEM	Signal Phase And Timing Extended Message

SSR	Sirius Satellite Radio
TAI	International Atomic Time scale
TCU	Transmission Control Unit
ToF	Time-of-Flight
UE	User Equipment
UPER	Unaligned Packet Encoding Rules
UTC	Coordinated Universal Time
UWB	Ultra Wide Band
VLBI	Very-Long-Baseline Interferometry
VRU	Vulnerable Road User
WGS	World Geodetic System
WGS84	World Geodetic System 1984

4 Position and Time entity introduction

4.1 Introduction

ITS applications such as specified in the Basic Set of Applications specification (BSA) ETSI TR 102 638 [i.2] require the exchange of position and time information as part of the information exchange among ITS-Ss. As initial ITS location based services, the Cooperative Awareness (CA) basic service ETSI EN 302 637-2 [i.3] and similar, the road traffic event Decentralized Environmental Notification (DEN) basic service ETSI EN 302 637-3 [i.4] are developed. These services and their data exchanges are dependent on position and time information. In this and the following clauses it is understood that "position" means **kinematic and attitude state** as defined in clause 5.4.1 which includes attitude and movement parameters including velocity, heading, horizontal speed and optionally others.

In order to realize road ITS safety related applications, ITS-Ss need to have an absolute knowledge about their position and have a common synchronized knowledge about time to be able to value information received from another ITS-Ss. To realize this absolute knowledge about position and time, an ITS-S may be equipped with a Global Navigation Satellite Systems (GNSS) making use of Galileo or GPS and/or other satellite navigation technologies, providing satellite positioning information to the PoTi entity.

Depending on the applications supported by an ITS-S, the qualitive requirements on the accuracy, integrity and reliability of the position and time references may vary. As the CA basic service (ETSI EN 302 637-2 [i.3]) specifies, road safety applications may require the ITS-S to transmit position and time information at intervals of about 10 times a second, while new applications such as Platooning requires intervals of ≥ 20 times a second.

ITS applications are based on the exchange of information among ITS-Ss and therefore ITS applications operating in one ITS-S are depending on the information provided by other ITS-Ss, a set of minimum requirements to be supported by all ITS-Ss needs to be agreed. As new ITS applications are constantly being developed these minimum requirements need to be set for a selective set of (grouped) ITS applications. At the current state an ETSI Release 1 set of ITS standards (ETSI TR 101 607 [i.10]) is the reference for the Release 1 equipment and therefore it provides the requirements for the Release 1 PoTi requirements.

Based on the current developments of new services and related analyses by EU projects further optional requirements are included.

The position and time (PoTi) service as identified in ETSI TS 102 894-1 [i.5] residing in the facility layer is an essential part of the ITS; it provides time and position information to all ITS applications and services.

In order to satisfy the application requirements and different Releases of application sets, the PoTi entity may include various methods to ensure the accuracy, integrity and reliability of the position and time references as required by the ITS applications supported by the ITS-S.

4.2 Service provided by the PoTi entity

The facility layer PoTi entity manages the position and time information for use by ITS applications, facility, network, management and security layers. For this purpose, it gets information from sub-system entities such as GNSS, sensors and other sub-system entities. Given the ITS application requirements in terms of position and time accuracy, PoTi may use augmentation services to improve the position and time accuracy. Various augmentation methods may be applied. PoTi may support these augmentation services by providing messages services broadcasting augmentation data. For instance, a roadside ITS-S may broadcast correction information for GNSS to oncoming vehicle ITS-S; ITS-Ss may exchange raw GPS data or may exchange terrestrial radio position and time relevant information. PoTi maintains and provides the position and time reference information according to the application and facility and other layer service requirements in the ITS-S.

5 PoTi functional description

5.1 PoTi in the ITS Domain

The ITS reference architecture is defined in ETSI EN 302 665 [i.1]. It defines the ITS Station (ITS-S) architecture as part of the ITS domain. In the ITS domain, at a particular time an ITS-S may be in a situation when no other ITS-Ss are active within its communication range, while at another moment it may be in a situation in which there are many ITS-Ss active within its communication range. An ITS Constellation (ITS-C) is a group of ITS-Ss that communicate with each other. ITS-Cs may overlap, and an ITS-S may be active in several ITS-Cs but in general not necessary in all as not all ITS-Cs need to overlap (see Figure 1).

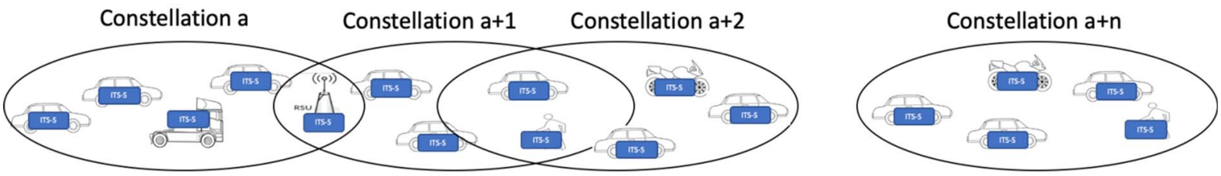

Figure 1: Momentary ITS-Cs in the ITS domain

5.2 ITS Constellation

ITS services are based on sharing information between ITS-Ss. Applications in ITS-Ss receive messages containing information from neighbouring ITS-Ss and use this to provide services in the receiving ITS-S. It is therefore essential that receiving ITS-Ss can identify the time and position relevance of the content of each message. ITS-Ss in the same ITS-C shall have a consistent understanding of position and time for the services they support. When ITS-C overlap, only those in the overlapping area shall have an understanding of position and time, of both constellations but other ITS-Ss not (see Figure 1).

ITS applications and services may have different time and position requirements. Depending on the ITS services to be supported by an ITS-S, the time and position accuracy requirements toward the facility service PoTi may differ but are required to be commonly agreed. To ensure that the existing ITS-Ss in an ITS-C can support each other's active ITS services, common minimum requirements are agreed based on the ITS Releases. Currently Release 1 and Release 2 ITS services are distinguished. Minimum common requirements for the Release 1 set of applications are defined in ETSI TR 102 638 [i.2]. Minimum requirements for Release 2 cannot be set at this time.

The PoTi entity of any ITS-S in a given ITS-C should ensure that $Tsys_n \approx T$ (T is the ITS Time) within this ITS-C.

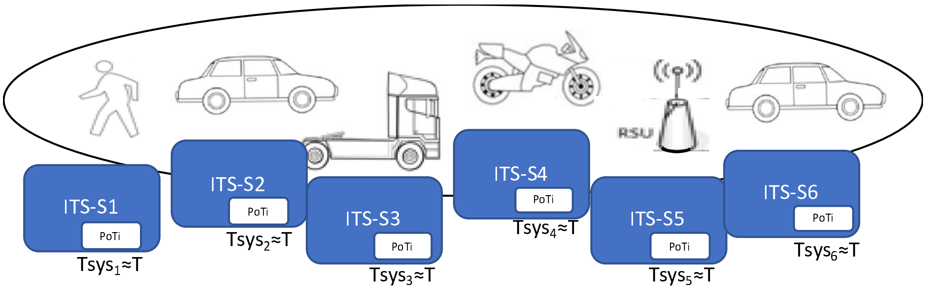

Figure 2: Momentary ITS-C

5.3 PoTi in the ITS Station (ITS-S) architecture

PoTi is a facilities layer entity that manages the **Position and Time information** required by the application, facility, network, management and security layers. It ensures ITS time synchronicity between the ITS-Ss in the ITS system, it maintains the **data quality** (e.g. by monitoring time deviation) and **manages updates** of the kinematic and attitude state and time. The PoTi entity may include augmentation services to improve the position and time accuracy, integrity, and reliability. Among these methods, communication technologies may be used to provide positioning assistance from mobile to mobile ITS-Ss and infrastructure to mobile ITS-Ss.

The PoTi entity interfaces with ITS applications and other facility layer entities in order to provide position and time information, such as CA basic service described in ETSI EN 302 637-2 [i.3] and DEN basic service described in ETSI EN 302 637-3 [i.4], C-ACC described in ETSI TR 103 299 [i.6] and CP described in ETSI TS 103 324 [i.7] basic service. Figure 3 presents PoTi in the ITS-S architecture according to ETSI EN 302 665 [i.1].

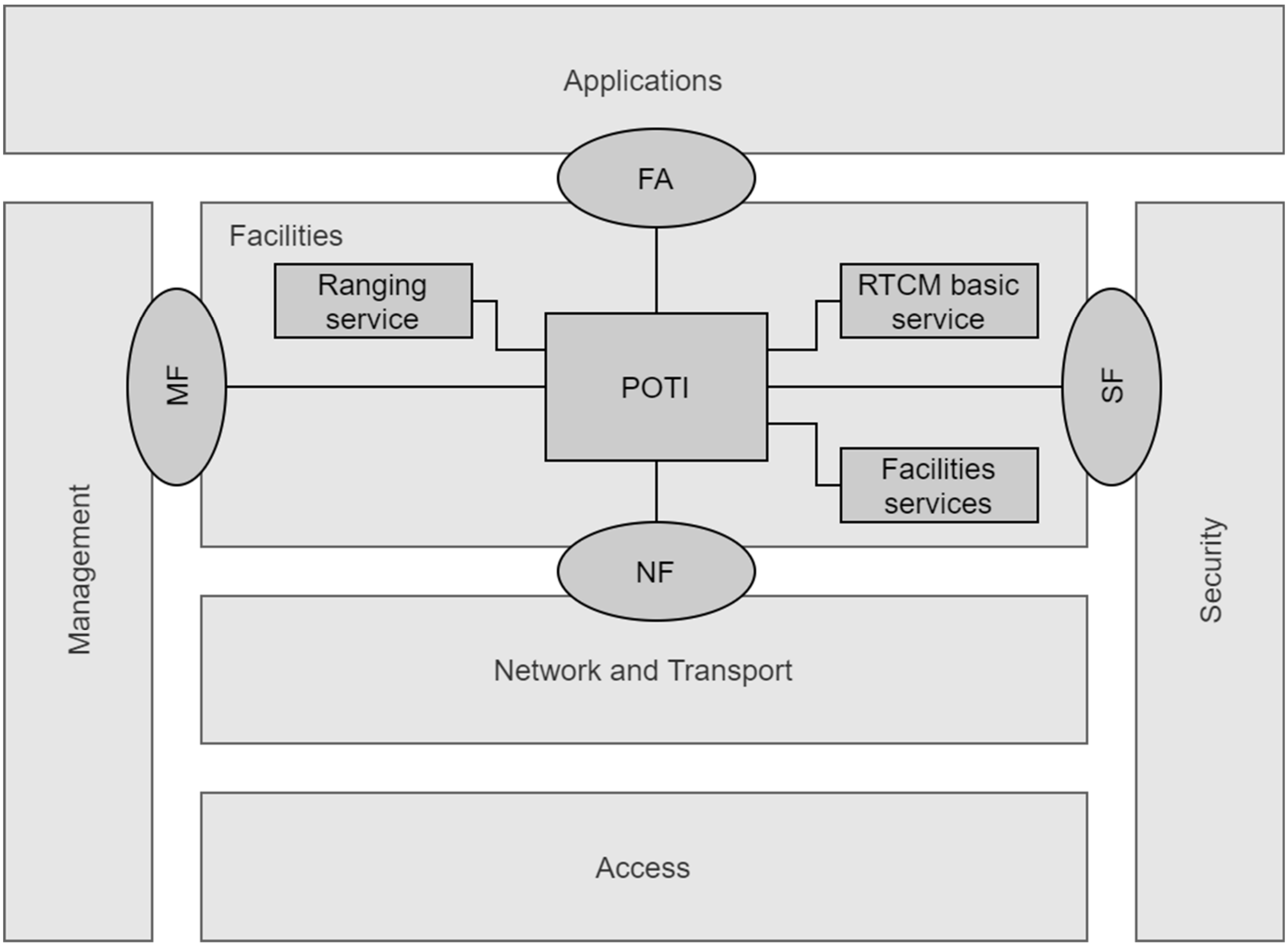

Figure 3: The PoTi entity its interfaces to other facilities entities via the FA-SAP, and its interfaces in the ITS-S architecture according to ETSI EN 302 665 [i.1]

5.4 PoTi entity functional architecture

5.4.1 General

Figure 4 illustrates functions and interfaces of the PoTi entity.

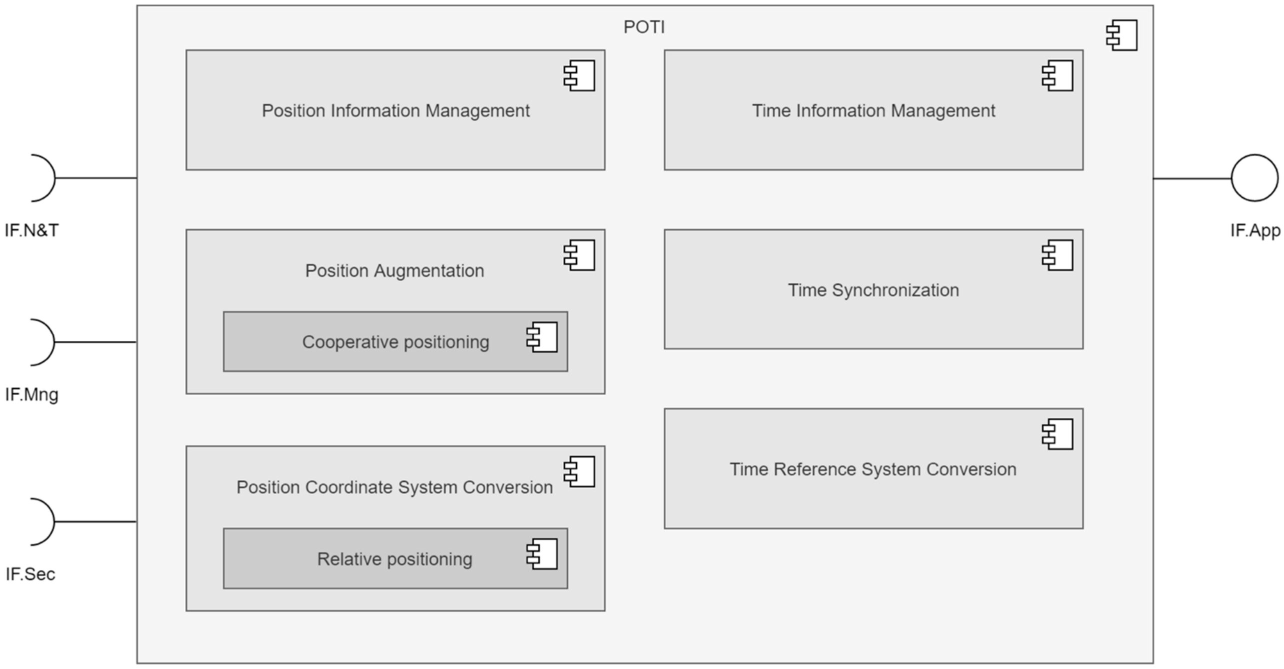

Figure 4: PoTi entity functional architecture

The functions are described in the following clauses. The interfaces are described in clause 5.5.

5.4.2 Position information Management

- The kinematic and attitude state of the rigid body contained in the ITS-S included position, velocity, acceleration, orientation, angular velocity and possible other motion related information. The position information at a specific moment in time is referred to as the kinematic and attitude **state** including time, of the rigid body.

NOTE 1: If not otherwise stated all these quantities are provided in 3D.

- In addition to the kinematic and attitude state, PoTi should also maintain information on the confidence of the kinematic and attitude state variables.

An ITS-S should at least be functional when the system of which it is part of is in operation. The PoTi entity should be functional when the ITS-S is operating.

NOTE 2: As for many implementations it takes time for the PoTi entity to provide proper information. The PoTi entity may be functional for a period of time when the system of which it is part of is not operational. Once the system is reactivated, the PoTi entity should validate the kinematic and attitude state and confidences whether it still meets the system requirements.

An ITS-S may use multiple means of positioning if they are available (e.g. GNSS, inertial sensors, odometer, cameras, terrestrial radio ranging, map matching, etc.). Depending on the applications and services an ITS-S needs to support an ITS-S could use single or multiple augmentation services to improve its position and time accuracy.

5.4.3 Position Augmentation

- The Position augmentation function uses externally sourced assistance data or measurements in order to improve positioning performance by eliminating system errors common to many ITS-Ss.
- Satellite based augmentation: in Europe, European Geostationary Navigation Overlay Service (EGNOS) is provided to improve GNSS position accuracy. RTK and SSR services are also augmentation services that can be used by GNSS receivers; they may be distributed across satellite channels or terrestrial communication links including from other ITS-Ss.
- Cooperative positioning: ITS-Ss may exchange information to improve the relative positioning. Ground based augmentation such as EGNOS, RTCM or SSR based (PPP-RTK) services can be distributed over terrestrial communications channels to augment GNSS data. R-ITS-S could transmit RTCM or SSR correction information to vehicle ITS-Ss, as specified in ETSI TS 103 301 [1].

5.4.4 Reference coordinate System Conversion

The reference coordinate System Conversion function converts the kinematic and attitude state between different reference systems, e.g. to and from local (vehicle) coordinate systems or ITRF14 or ETRS89. Relative positioning is a sub function of Reference coordinate System Conversion and involves the conversion from the WGS84 [6] coordinate system to local coordinates systems, as e.g. used in DENM traces.

The Reference coordinate System Conversion is used for instance to describe relevance areas:

- Where the relevance area is an ellipse or a rectangle, the Cartesian coordinates of the area center and of the current position shall be calculated as specified in the ETSI EN 302 931 [11]. For this purpose, the 'local tangent plane' method is recommended, or another method delivering the same accuracy.

5.4.5 Time information Management

ITS time shall be defined as a time based on TAI. Epoch of ITS time is set to 2004-01-01T00:00:00Z, that is 0 seconds on 1st of January 2004 UTC. **ITS time** is the general **time base** for all ITS-Ss. An ITS-S's representation of ITS Time is referred to as the **station clock**. A moment in time, or instant, after the epoch can be represented by a timestamp. A timestamp is the duration of the time interval between the epoch and the instant, derived from the station clock according to IEC 60050 [i.14].

Time Information Management manages the quality of the station clock, handles updates of the ITS-S time information and provides the time information to other entities in the ITS-S.

For the ITS-S time information the same activation requirements are valid as for ITS-S position information as identified in clause 5.4.2.

5.4.6 Time synchronization

The ITS Station should synchronize its station clock by means of one or more external time services (GNSS, NTP), taking into account accuracy, integrity and reliability of the external service.

NOTE: ITS-Time is based on TAI, and therefore has no special treatments of leap-seconds that are introduced in UTC at specific moments in time. UTC itself is based on counting SI seconds since an epoch, similar to ITS-Time. However, several time synchronization protocols, like NTP, modify the clock that counts the number of SI seconds since the epoch, to facilitate easier conversion from clock counter values to UTC date/time. Therefore, care should be taken when using such synchronization services to correctly treat the insertion of UTC leap seconds, specifically also during the insertion of the leap second.

5.4.7 Time reference system conversion Service

- The time reference system conversion takes care of converting from ITS Time to other time reference systems. PoTi should support the conversion between ITS Time and UTC and vice versa when required by applications. Support for other time reference systems can also be supported.

NOTE: UTC is used as the time basis for time information in several messages, like SPATEM in ETSI TS 103 301 [1].

5.5 PoTi Interfaces

5.5.1 Interface to ITS applications (FA-SAP)

PoTi provides position and time information to ITS applications residing in the ITS-S via the interface IF.Appl as illustrated in Figure 4. In one possible implementation, the interface IF.Appl may be implemented as SF-SAP as illustrated in Figure 3.

In one possible implementation of this interface, the position and time information (including confidence values) may be provided by the PoTi module upon request or automatically upon a given trigger, e.g. when the system receives an update.

Via the FA-SAP interface security and integrity information could be provided by the PoTi service originating source entity (such as on-board sensors or GNSS).

Although PoTi specifies checks for integrity and security, however these checks are also done by misbehaviour detection functions.

Interfaces to local sensor in an ITS station may exist. PoTi could provide an interface to functions harmonizing local sensor data input.

An Application layer function may receive data from POTI using the parameters shown in Table 1.

The following minimum data set may be made available via IF.App. Additional data may be made available. All data shall refer to reference point 0, see clause 6.2. Data for other reference points may be provided. All data provided need to fulfil the specifications and requirements stipulated in clause 5.4 and clause 6.

Table 1: FA-SAP minimum data set

Category	Data	Data requirement	Mandatory/Optional
Reference point	Reference point identifier	See clause 6.2	Conditional: mandatory only when data for multiple reference points are provided
Time	Timestamp	See clause 5.4.4	Mandatory
Position	Latitude	See clause 6.1	Mandatory
	Longitude	See clause 6.1	Mandatory
	Altitude	See clause 6.1	Optional
Motion	Horizontal Speed	See clause 6.1	Optional
	Vertical Horizontal Speed	See clause 6.1	Optional
	Heading	See clause 6.1	Optional
Confidence	Horizontal position confidence (semiMajorAxis, semiMinorAxis, semiMajorOrientation)	See clause 6.3.2.1	Optional, but if provided, then all data needs to be provided
	Vertical position confidence	See clause 6.3.2.2	Optional
	Horizontal Speed confidence	See clause 6.3.2.3	Optional
	Heading confidence	See clause 6.3.2.4	Optional

For position augmentation and time synchronization, ITS-S may receive position and time correction information via the FA-SAP originating from an application having access to such information (e.g. via satellite communication). PoTi processes the received position augmentation and time synchronization information and realizes the position augmentation and time synchronization.

Information received via this interface may include:

- EGNOS information;
- EDAS data;
- GRM data;

- RTCM correction data as specified RTCM STANDARD (see clause 7.2);
- Compact SSR or PPP-RTK correction data similar to that specified in IS-QZSS-L6-001 [i.15];
- Network time protocol data (IETF RFC 5905 [i.13]);
- Precision Time protocol data (IETF RFC 8173 [i.16]);
- Other data for position augmentation and time synchronization.

5.5.2 Interfaces to the Networking and Transport Layer (NF-SAP)

PoTi may exchange information with the networking & transport layer via the functional interface management entity via the functional interface IF.N&T as illustrated in Figure 4. This interface may be implemented as NF-SAP as illustrated in Figure 3. For example, the Geonetworking uses this interface to receive position and time information from the PoTi entity.

A networking & transport layer function may receive data from POTI using the parameters shown in Table 2. Additional data may be made available. All data shall refer to reference point 0, see clause 6.2. Data for other reference points may be provided. All data provided need to fulfil the specifications and requirements stipulated in clause 5.4 and clause 6.

Table 2: NF-SAP minimum data set

Category	Data	Data requirement	Mandatory/Optional
Time	Timestamp	See clause 5.4.4	Mandatory
Position	Latitude	See clause 6.1	Mandatory
	Longitude	See clause 6.1	Mandatory
Confidence	Horizontal position confidence (semiMajorAxis, semiMinorAxis, semiMajorOrientation)	See clause 6.3.2.1	Mandatory

5.5.3 Interfaces to the Management entity (MF-SAP)

PoTi may provide position and time information to other layers of the ITS-S via the management entity via the interface IF.Mng as illustrated in Figure 4. The interface IF.Mng may be implemented as SF-SAP as illustrated in Figure 3.

The PoTi entity may be managed via IF.Mng to configure its internal functioning, or to configure the details of external services to use. The functions are implementation specific, and out of scope of the present document.

5.5.4 Interfaces to the Security entity (SF-SAP)

PoTi may provide position and time information to the security entity of the ITS-S via the interface IF.Sec as illustrated in Figure 4. In one possible implementation, The interface IF.Sec may be implemented as SF-SAP as illustrated in Figure 3. The PoTi entity may use functions of the security entity to authenticate a given information provider (e.g. GNSS). The Security entity populating the security header uses this interface to receive position and time information from the PoTi entity.

A Security layer function may receive data from POTI using the parameters shown in Table 3.

The following minimum data set may be made available via IF.Sec. Additional data may be made available. All data shall refer to reference point 0, see clause 6.2. Data for other reference points may be provided. All data provided need to fulfil the specifications and requirements stipulated in clause 5.4 and clause 6.

Table 3: SF-SAP minimum data set

Category	Data	Data requirement	Mandatory/Optional
Time	Timestamp	See clause 5.4.4	Mandatory
Position	Latitude	See clause 6.1	Mandatory
	Longitude	See clause 6.1	Mandatory
	Altitude	See clause 6.1	Optional

5.5.5 Interfaces to other Facility layer entities

PoTi provides position and time information to other entities and services residing in the Facility layer as illustrated in Figure 3 via the functional interface IF.Ap as illustrated in Figure 4.

This interface may be realized as described in clause 5.5.1. For example, CA basic service triggers the transmission of Cooperative Awareness Message (CAM) with a specific transmission interval. For vehicle ITS-S, this transmission interval is defined based on the vehicle position change as defined in clause 6.1.3 of ETSI EN 302 637-2 [i.3]. In order to ensure the data freshness of CAM, vehicle ITS-S could require that PoTi provides the position and time update with a specific rate e.g. 10 Hz for Release 1 application. For Release 2 higher rates are being considered. For DEN basic service operation as specified in ETSI EN 302 637-3 [i.4], an ITS application could detect a traffic event and send a request to PoTi in order to obtain the current ITS-S position and time in order to estimate the event position and event detection time.

The following data set shall be made available. Additional data may be made available. All data shall refer to reference point 0, see clause 6.2. Data for other reference points may be provided. All data provided need to fulfil the specifications and requirements stipulated in clause 5.4 and clause 6.

Table 4: Internal Facility layer minimum data set

Category	Data	Data requirement	Mandatory/Optional
Reference point	Reference point identifier	See clause 6.2	Conditional: mandatory only when data for multiple reference points are provided
Time	Timestamp	See clause 5.4.4	Mandatory
Position	Latitude	See clause 6.1	Mandatory
	Longitude	See clause 6.1	Mandatory
	Altitude	See clause 6.1	Optional
Motion	Horizontal Speed	See clause 6.1	Optional
	Vertical Horizontal Speed	See clause 6.1	Optional
	Heading	See clause 6.1	Optional
Confidence	Horizontal position confidence (semiMajorAxis, semiMinorAxis, semiMajorOrientation)	See clause 6.3.2.1	Optional, but if provided, then all data needs to be provided
	Vertical position confidence	See clause 6.3.2.2	Optional
	Horizontal Speed confidence	See clause 6.3.2.3	Optional
	Heading confidence	See clause 6.3.2.4	Optional

6 Position and time requirements

6.1 Requirements related to PoTi functions

The PoTi entity shall provide kinematic and attitude state information (see clause 5.4.2). The state information shall include 3D position and 2D velocity information and may include other information of one or more reference points. The kinematic and attitude state information shall be consistent, i.e. all information that are part of the same state, shall refer to the same moment in time.

NOTE 1: Any inaccuracies that might result from time-related effects, such as interpolation or extrapolation, effects from using multiple internal clocks, etc., should be taken into account in the confidence of the state variables.

The World Geodetic System 84 (WGS84 [6]) shall be used as the reference coordinate system as specified in ETSI TS 102 894-2 [10]. Horizontal position information shall be interpreted as the latitude/longitude position based on the WGS84 Ellipsoid. Vertical position information (altitude) shall be interpreted as height above WGS84 Ellipsoid. Alternative altitude interpretations using Geoid definitions (e.g. relative to mean sea level) shall not be used.

The PoTi entity shall provide velocity information. Velocity information refers to the velocity of the reference position of the ITS-S, unless otherwise noted. A 3D velocity vector shall be decomposed in a 2D vector (the horizontal velocity vector) by projecting the 3D vector on the WGS84 Ellipsoid, and a vertical speed by projecting the velocity vector on the normal vector on the WGS84 Ellipsoid. The horizontal speed shall be the length of the horizontal velocity vector, unless otherwise noted. The heading shall be the orientation of the horizontal velocity vector with respect to the WGS84 North (clockwise), unless otherwise noted.

NOTE 2: This definition of horizontal speed and heading does not consider possible vertical component of the velocity vector at this time.

NOTE 3: The vertical speed is positive when the reference position is moving upwards, away from the center of the earth, and negative when the reference position is moving downwards.

NOTE 4: NGA and its predecessor organizations have ensured that WGS84 [6] is consistent with the most recent ITRF realization. The purpose of this alignment is to adhere to international standards and pursue the highest possible level of practical global reference frame accuracy. The ITRF incorporates multiple methods to realize their series of reference systems such as Satellite Laser Ranging (SLR) and Very-Long-Baseline Interferometry (VLBI) that NGA does not include. Constraining the WGS 84 reference frame to align with ITRF as closely as possible allows the WGS84 [6] reference frame to take advantage of those methods without directly incorporating them into the coordinate determination software. This alignment is necessary for interoperability with other Global Navigation Satellite Systems (GNSS). While GPS is currently the most widely used GNSS, there are other systems operating or being developed. The USA bi-lateral agreement with the European Union states that WGS84 [6] and ITRF will be closely aligned to support interoperability between GPS and Galileo.

The vehicle orientation shall represent the orientation of the vehicle coordinate system (ISO 8855 [7]) in which the ITS-S is contained relative to the ground plane based on the WGS84 ellipsoid (local navigation coordinate system). It shall consist of vehicleOrientationAngle (yaw-angle, clockwise rotation w.r.t. North), pitchAngle (angle between the ground plane and the vehicle's X axis, positive values for "nose down") and rollAngle (angle between the ground plane and the vehicle's Y axis, positive values for "rolling to the right"). The vehicleOrientationAngle is different from the vehicle heading.

NOTE 5: The ground plane based on the WGS84 ellipsoid is slightly different to the ground plane definition of ISO 8855 [7], which refers to a plane that is perpendicular to the gravity vector.

NOTE 6: In Figure 5, pitchAngle and rollAngle are zero.

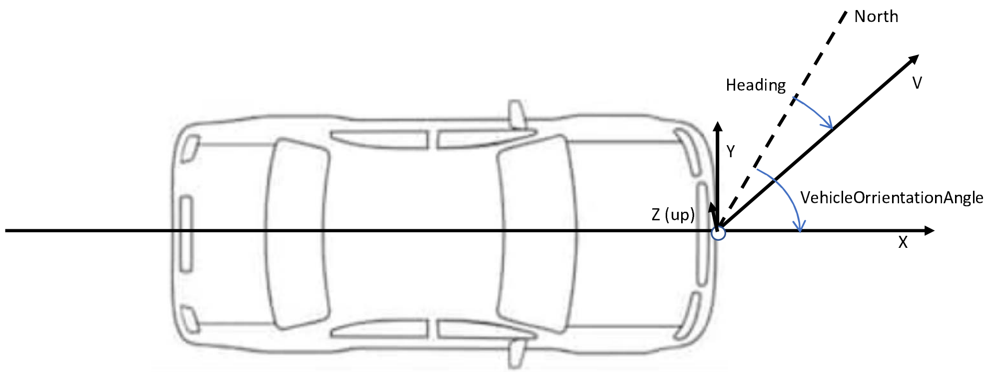

Figure 5: Vehicle Heading and Orientation Angle

NOTE 7: Based on the drift of European Terrestrial Reference System (ETRS89) [i.9], which is fixed to the continental plate of Europe, of 2,5 cm/year in WGS84 [6] it needs to be noted that an ITS-S needs to be aware what referencing system is used. When an augmentation service such as an RTK system is used, differences may need to be compensated. Similar drifts of other continents also may need to be taken into account.

Vehicle accelerations shall be in Vehicle Coordinate System and based on the Center of Gravity of the empty load vehicle. They may include LateralAcceleration, LongitudinalAcceleration and VerticalAcceleration.

Vehicle rotational velocities shall be in Vehicle Coordinate System and based on the Center of Gravity of the empty load vehicle. They may include YawRate, PitchRate and RollRate.

Curvature shall represent the inverse of the radius of the current movement of the ITS reference point, projected on the WGS84 [6] Ellipsoid, being positive for left turns.

The PoTi entity shall implement functions to maintain its awareness of its position and other state information irrespectively of the position provider service used (e.g. GNSS). The PoTi entity shall be able to estimate the confidence of its state information as well as detect if the information it possesses is unreliable.

An ITS-S shall estimate its time accuracy, i.e. the difference between the station clock and ITS-time.

6.2 ITS-S reference position

6.2.1 Introduction

Road user equipment and Road Infrastructure equipment may be equipped with an ITS-S to realize ITS services. For each ITS equipped user the reference position shall be specified. Currently, reference positions for the following types of road user equipment and road infrastructure equipment are identified:

- Passenger Cars and small Vans.
- Trucks.
- Busses.
- Motorcycles.
- Bicycles or mopeds.
- Pedestrians.
- Special vehicles.
- Tram.
- Roadside Equipment

NOTE: For the reference position, the role is not important.

The ITS-S reference position for each of these types are presented in the following clauses. Lengths and offsets shall be determined based on ISO 8855 [7].

The ITS-S reference position is the anchor point of a bounding box. The bounding box extends from the ITS-s reference position upwards (Height) and backwards (i.e. in the opposite direction of the vehicleOrientationAngle, Length) and side wards (symmetrically to the left and right, Width).

6.2.2 ITS-S reference position for passenger cars

For a passenger car or small van e.g. a vehicle with 2 axels, 2 wheels per axel, the ITS-S reference position shall refer to ground position at the center point of the front side of the bounding box of the vehicle (with regards to the forward driving direction). From the bounding box the mirrors and possible similar extensions as illustrated in Figure 6 are excluded. Mirrors and other extensions may be described by a separate bounding box and positioned relative to the reference position.

NOTE: The GNSS antenna may be installed at any position in the vehicle, including other than the reference position of the vehicle ITS-S, as illustrated in Figure 6.

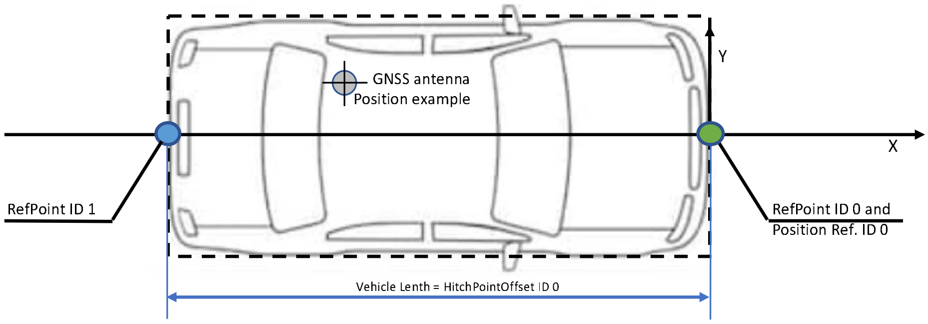

Figure 6: Vehicle reference position

A passenger car or van includes 2 reference points identified as RefPoint ID 0 and RefPoint ID 1. RefPoint ID 0 is identical to the reference position. RefPoint ID 1 is identified by the size of the Vehicle Length away from the reference position ID 0 in the opposite direction along the vehicle's longitudinal axis x.

Any RefPoint on the vehicle other than RefPoint ID0 is derived from the geometric extension relative to RefPoint ID 0. These are not expressed in terms of a WGS84 Position.

In case of a trailer attached to the end of a vehicle, as depicted in Figure 7, the RefPoint ID X of the trailer may be offset from the RefPoint ID 1 from the towing vehicle as indicated by hitchOffset provided in the direction of the x-axis of the coordinate system originating at RefPoint ID 1.

The reference position of a trailer (RefPoint ID X) shall refer to ground position at the center point of the front side of the bounding box of the trailer as depicted in Figure 7. Extensions may be described by a separate bounding box and positioned relative to this reference position.

In the following combinations the HitchOffset is not considered but in practice it may be applicable and, in those cases, it needs to be included. RefPoint ID x may be shifted with a distance of the HitchOffset.

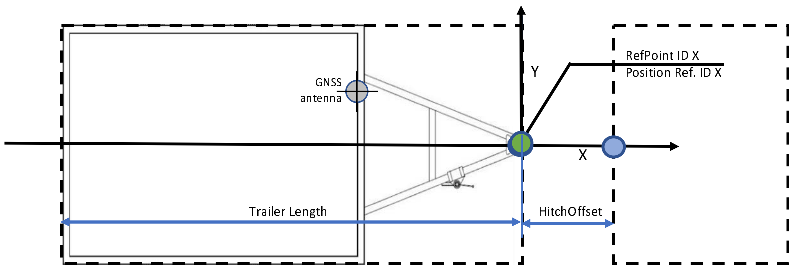

Figure 7: Small and large trailer reference position

In most cases small trailers are not equipped with an ITS-S, in such case the leading vehicles may provide information about the trailer. The vehicle may provide the total length of the trailer, the RefPoint ID 1 and the angle the trailer makes as defined by RefPointAngle ID 1 in Figure 8. The vehicle may be equipped to detect such angle.

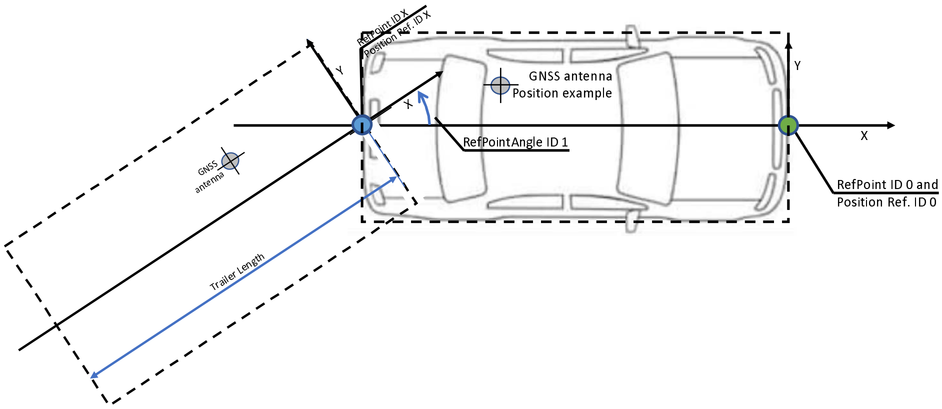

Figure 8: Vehicle/small trailers combination

6.2.3 ITS-S reference position for Trucks

Trucks can have different configurations. Standard rigid trucks or basic truck-trailers and combinations can be extended in different ways as shown in Figure 9 and Figure 10.

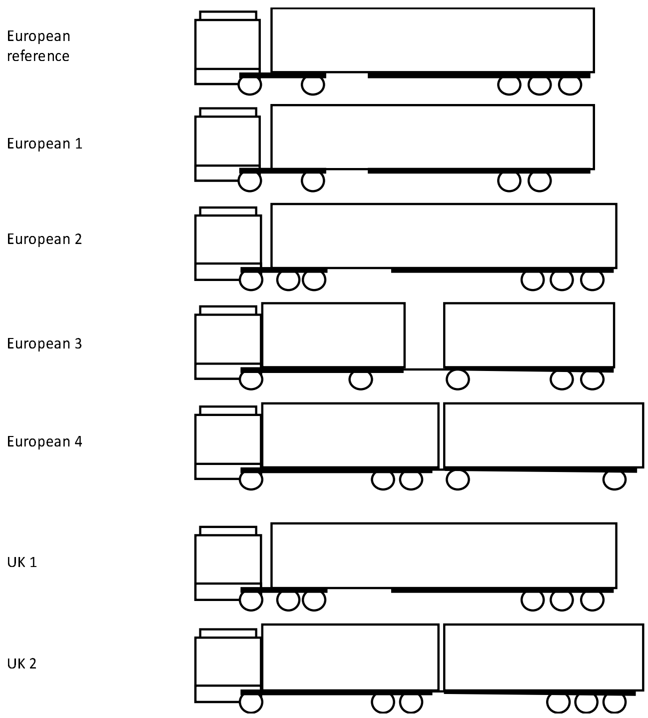

Figure 9: European Truck configurations

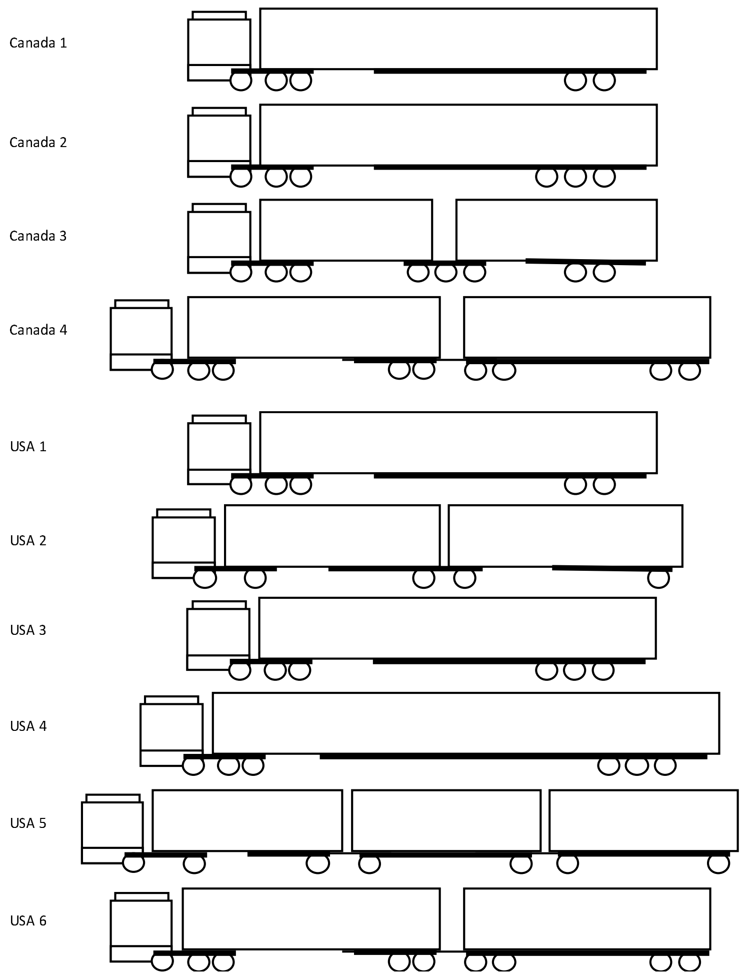

Figure 10: Other Truck configurations

For the standard rigid truck or tractor truck, the ITS-S reference position shall refer to ground position at the center point of the front side of the bounding box of the truck (with regards to the forward driving direction). From the bounding box the mirrors and possible similar extensions as illustrated are excluded. Mirrors and other extensions may be described by a separate bounding box and positioned relative to the reference position. A representation of the standard rigid truck and the tractor truck are depicted in Figure 11 and Figure 12. For both the RefPoint ID 0 shall have the same position as the reference position. Only the RefPoint ID 1 position is different. For a standard rigid truck, it is located at the center point of the back side of the bounding box of the truck. For the tractor truck it is located at the overhanging turning point.

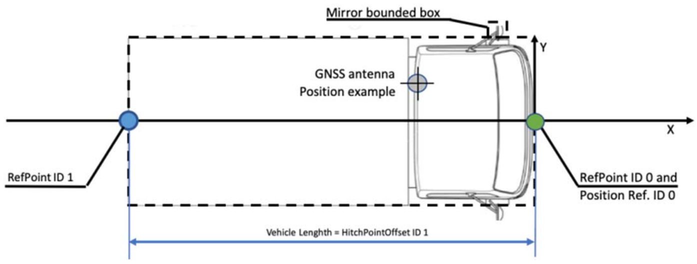

Figure 11: Standard rigid truck reference position

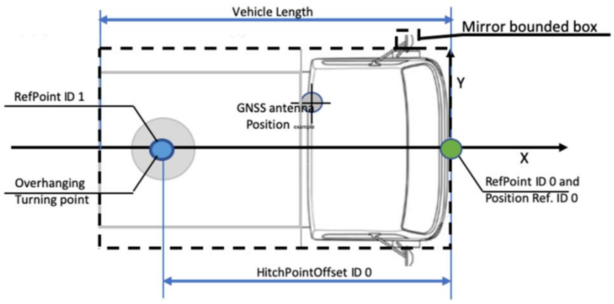

Figure 12: Tractor truck reference position

NOTE: The GNSS antenna may be installed at any position in the truck other than at the reference position of the vehicle ITS-S.

Besides the small or basic trailer as defined in Figure 7, 3 types of larger trailers are identified. In case 4 or more wheeled trailer are equipped with an ITS-S as depicted in Figure 13, the ITS-S reference position is as specified for the small trailer in Figure 7.

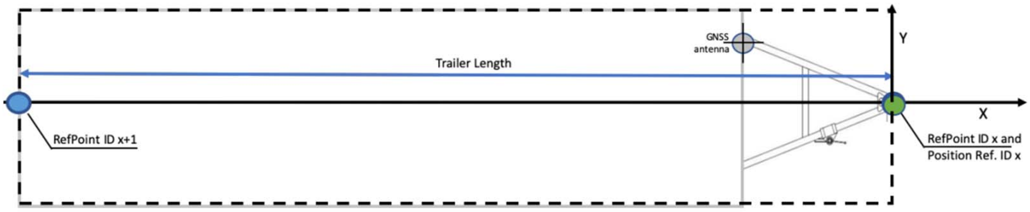

Figure 13: 4 or more wheeled larger trailer reference position

For overhanging trailers 2 configurations are identified as depicted in Figure 14. When ITS-Ss are implemented in these trailers, the ITS-S reference position shall refer to the ground position of the overhanging turning reference point (RefPoint ID X). The relation with the bounding box shall be identified by the FrontOverhang ID X and the RearOverhang ID X and when applicable ExtRearOverhang ID X. The sum of these length shall be equal to the total trailer length. From the bounding possible extensions as illustrated are excluded. These extensions may be described by a separate bounding box and positioned relative to the reference position. Extensions may be described by a separate bounding box and positioned relative to the reference position.

A trailer may be equipped with a capability to connect an additional overhanging trailer. In such case the ITS-S shall provide information about the second overhanging turning point RefPoint ID X+1 and the ExtRearOverhang ID X.

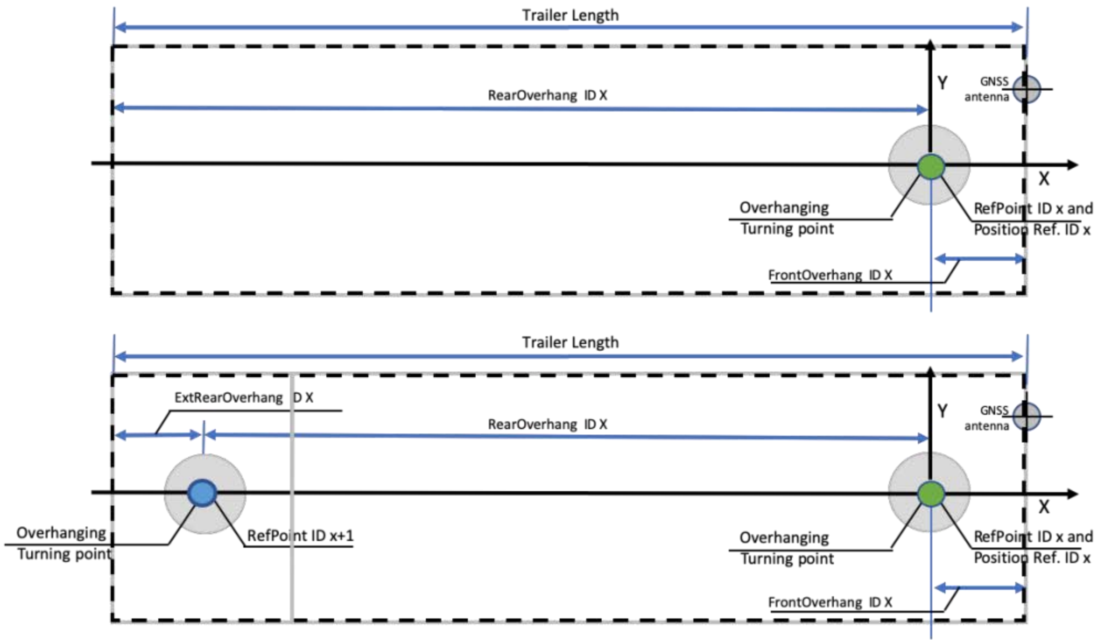

Figure 14: Overhanging trailer reference position

A trailer may include a turntable drawbar and thus an own front turning axle instead of a rigid drawbar. Such a trailer is modelled as two trailers: ID X for the front turning axle and ID X+1 as overhanging trailer (Figure 15).

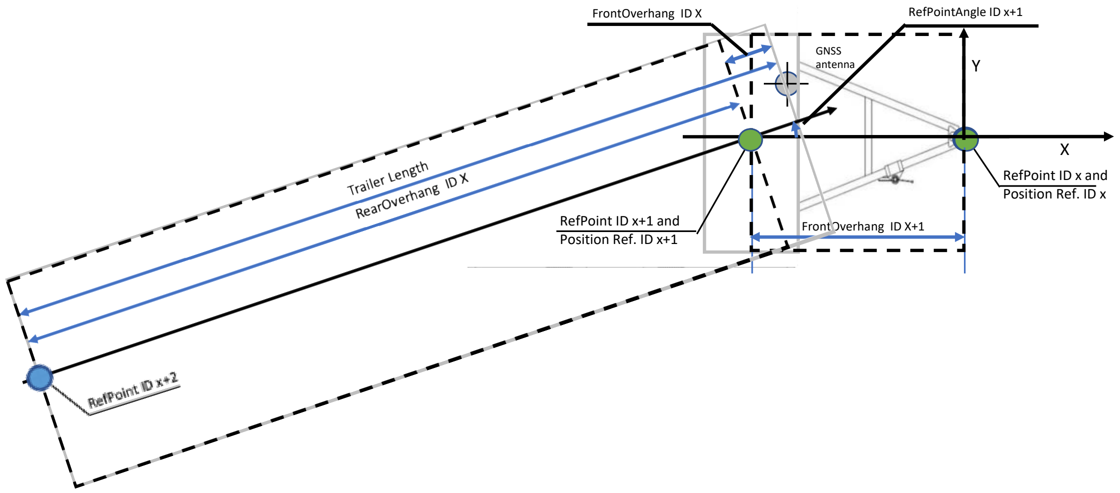

Figure 15: Trailer with own front turning axle reference positions

In case there are no ITS-S in the trailer the truck ITS-S may provide information about the type, length and overhang distances to other ITS-Ss. When angle sensors are implemented the truck ITS-S may provide the angles of each of the RefPoints as well (e.g. RefPointAngle ID 1 and ID 2). Different trailer combinations are depicted in Figure 16, Figure 17, Figure 18 and Figure 19. Angles shall be described in a reference frame originating at the corresponding RefPoint expressing the rotation of this reference frame relative to a situation in which the x-axes of the previous RefPoint are aligned.

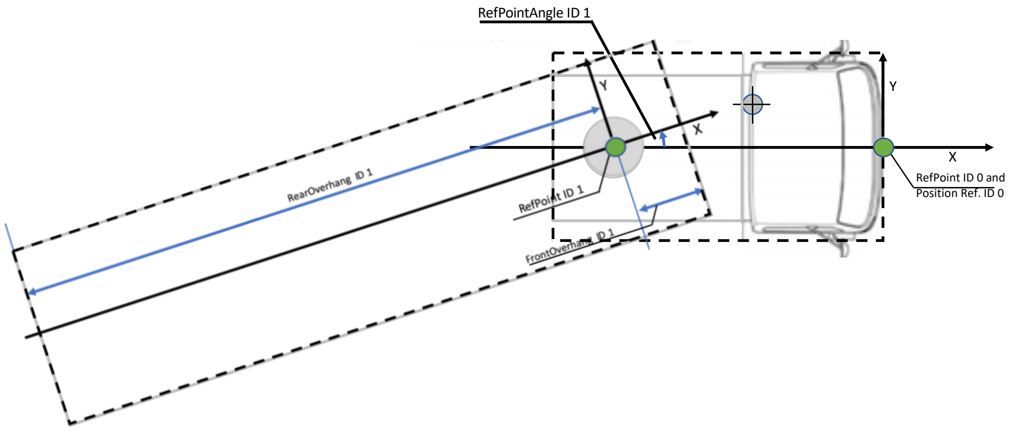

Figure 16: Truck with single overhang trailer

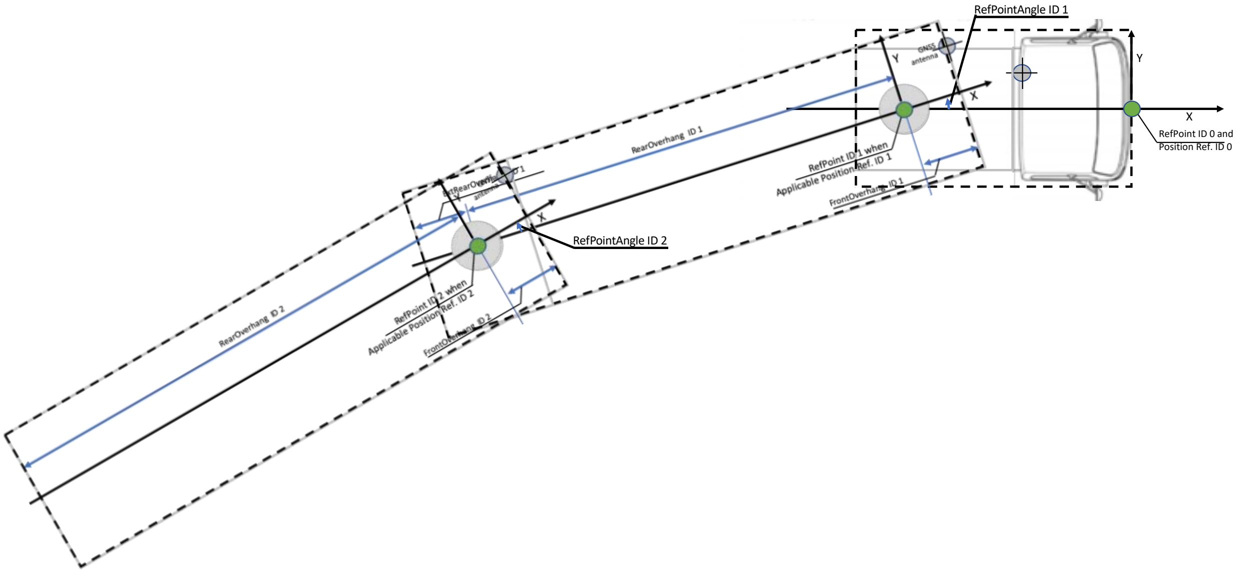

Figure 17: Truck with two overhang trailers

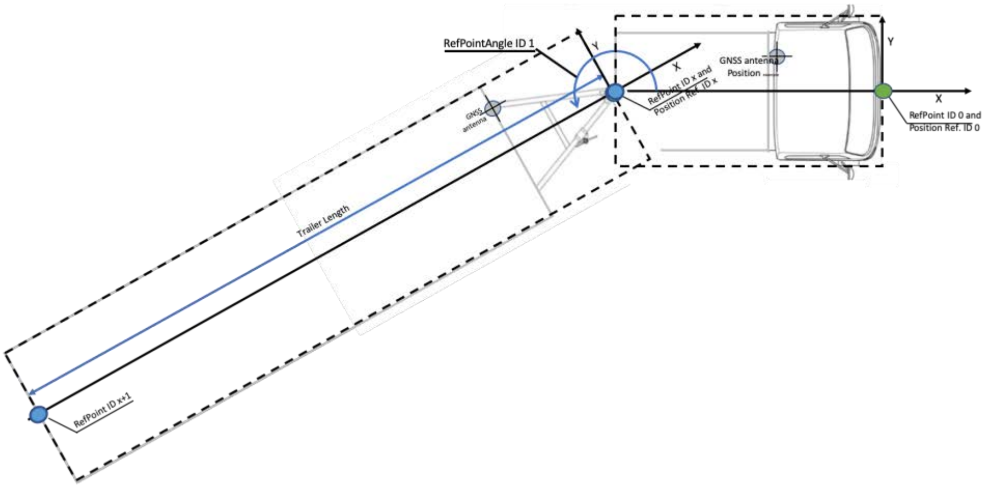

Figure 18: Truck with single none overhanging trailer

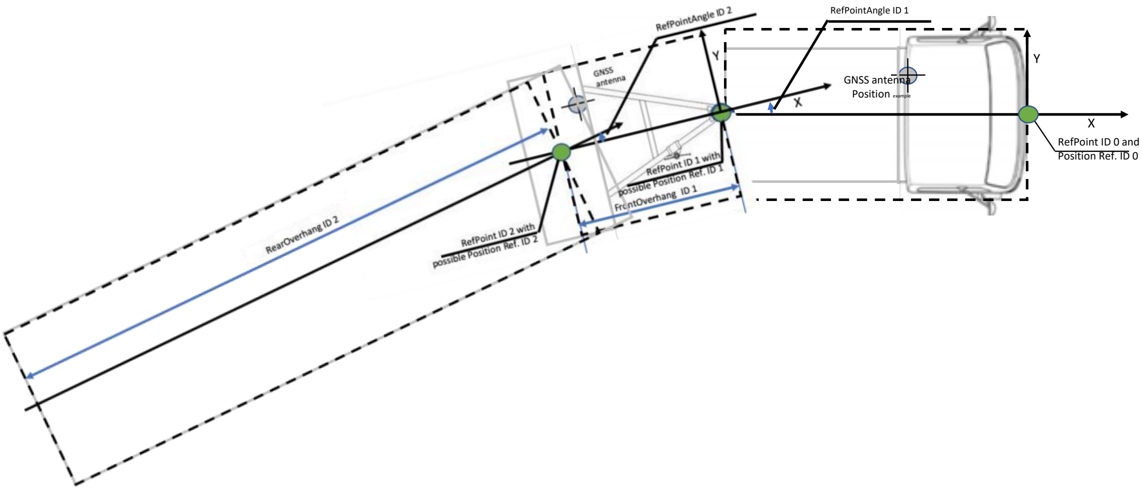

Figure 19: Truck with trailer with own turning axe

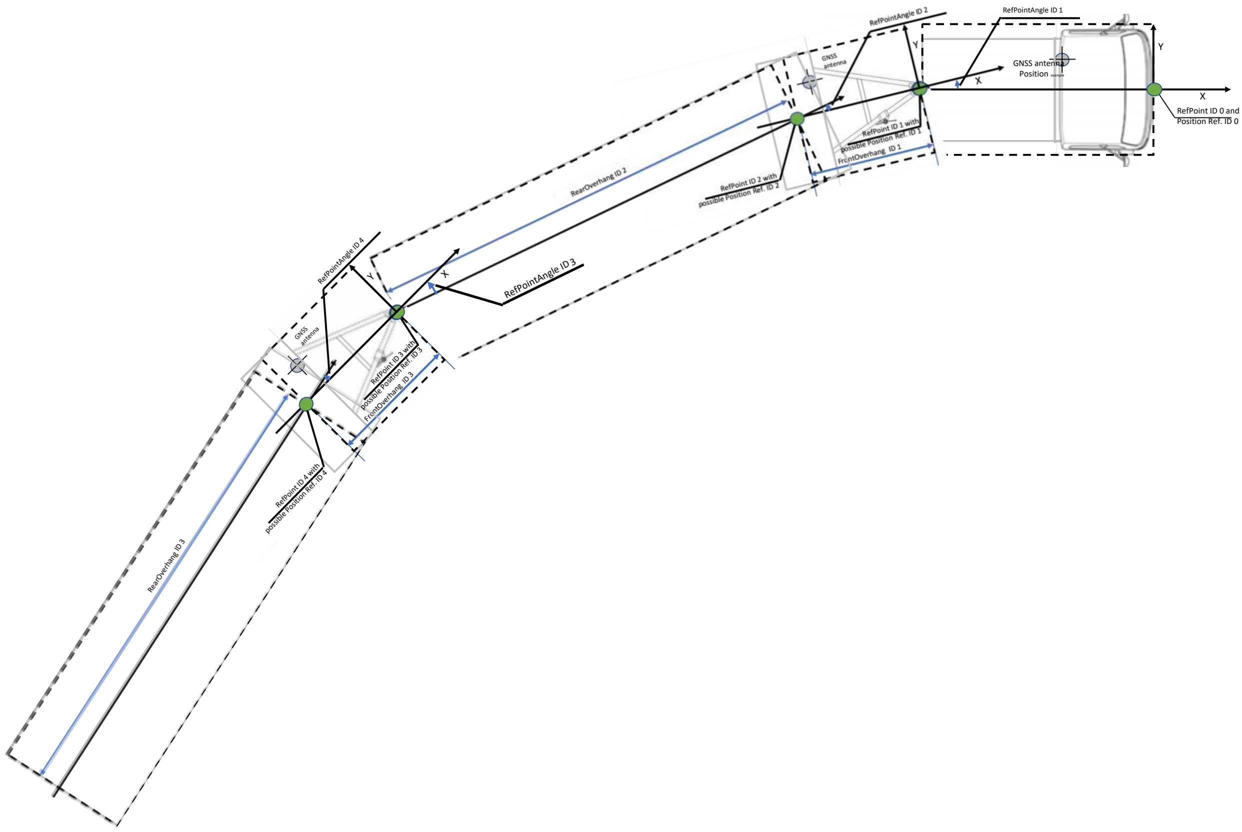

Figure 20: Truck with 2 trailers with own turning axes

6.2.4 ITS-S reference position for Busses

For busses the ITS-S reference position shall refer to ground position at the center point of the front side of the bounding box of the bus (with regards to the forward driving direction). From the bounding box the mirrors and possible similar extensions as illustrated are excluded. Mirrors and other extensions may be described by a separate bounding box and positioned relative to the reference position. With the aforementioned exception of mirrors, the length of the bounding box may include fixed attachments to the bus (such as a ski box at the rear of the bus, or a permanent bicycle rack at the front of the bus). In case the bus includes a bending extension (articulated bus), this extension is handled the same as a trailer and the bus ITS-S shall provide beside the vehicle length also the trailer length and the RefPointAngle ID 1 value. A bus may also pull a trailer. Such trailer may be equipped with its own ITS-S. In case it does not have an ITS-S, the bus ITS-S may additionally provide information such as the trailer length and RefPointAngle ID 1 (see Figure 22).

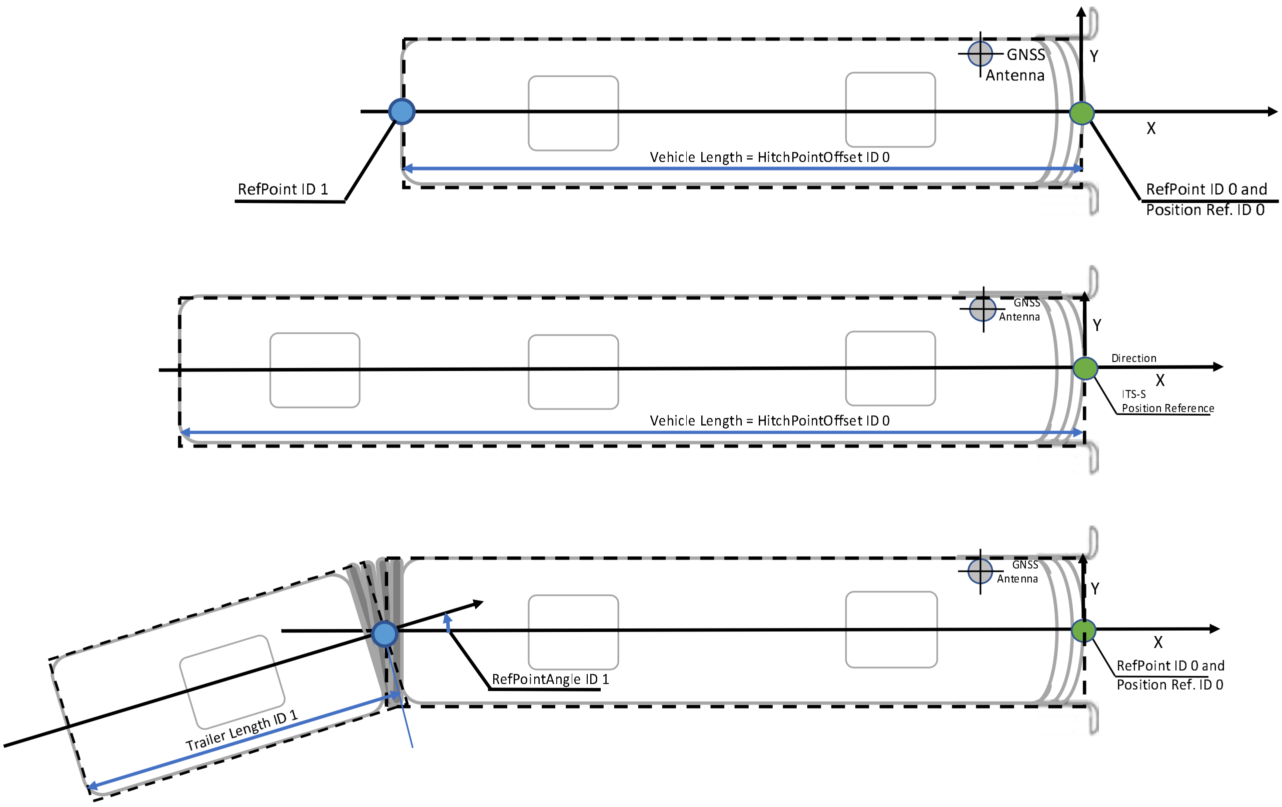

Figure 21: Basic bus configurations

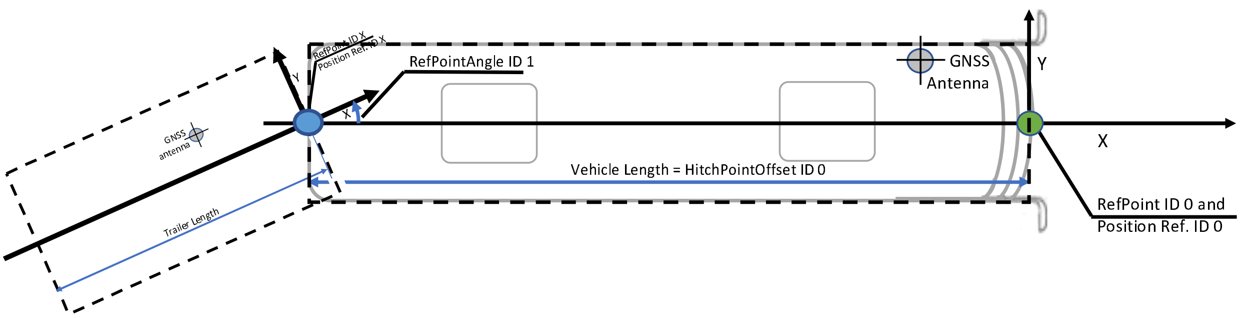

Figure 22: Bus with trailer

6.2.5 ITS-S reference position for Motorcycles, mopeds and bicycles

Motorcycles, mopeds and bicycles basically have similar shapes. When they are equipped with an ITS-S, the ITS-S reference position shall refer to ground position at the center point of a non-tilted bounding box representing the currently covered area of the Motorcycle, moped or bicycle in the best possible way. Possible solutions are shown in Figure 24 for fixed bounding boxes and Figure 25 for dynamic bounding boxes. In case a motorcycle, moped or bicycle pulls a trailer, the motorcycle, moped or bicycle ITS-S shall provide beside the vehicle length also the trailer length and the RedPointAngle ID 1 value (see Figure 26).

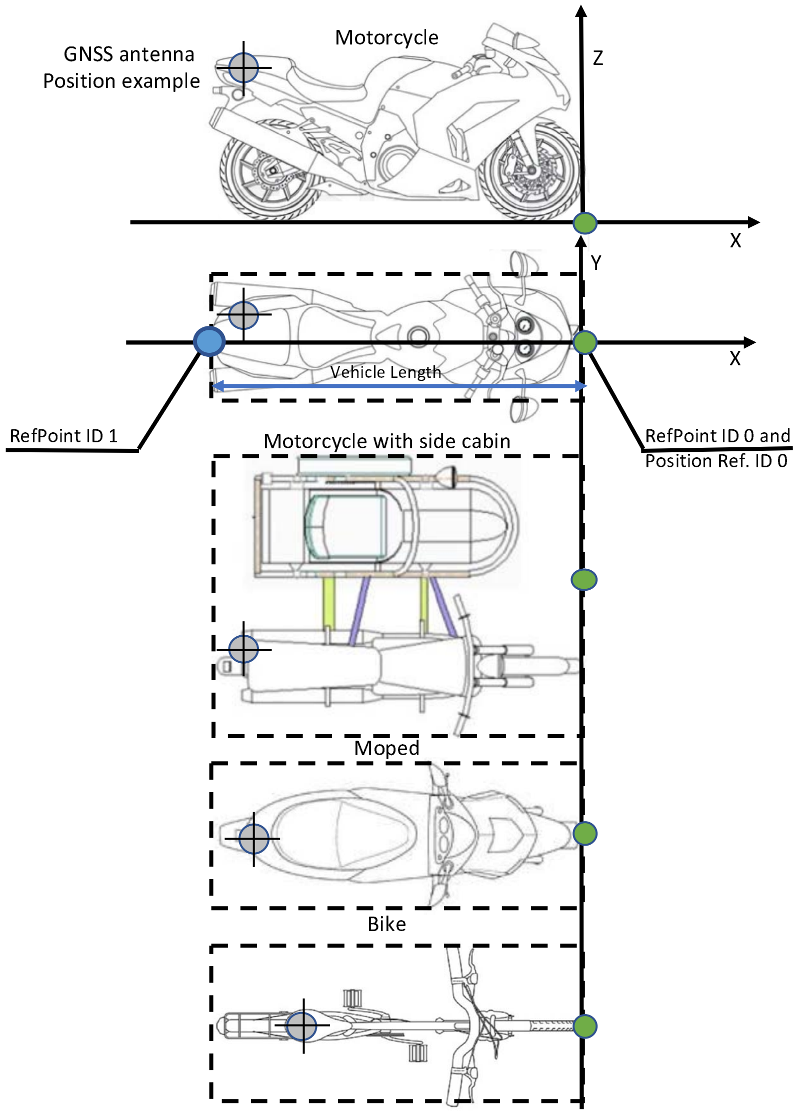

Figure 23: Motorcycle, moped and bicycle reference position

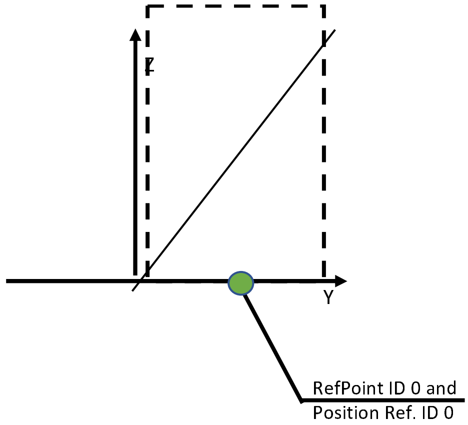

Figure 24: Motorcycle, moped and bicycle reference position in tilted position with fixed bounding box

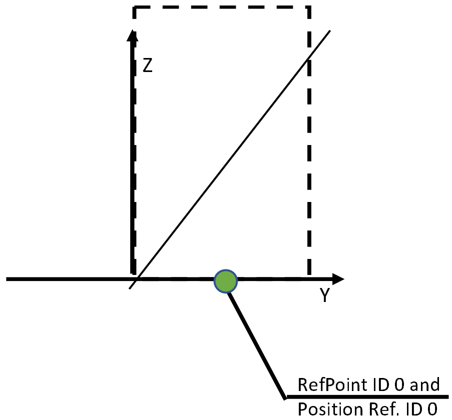

Figure 25: Motorcycle, moped and bicycle reference position in tilted position with dynamic bounding box

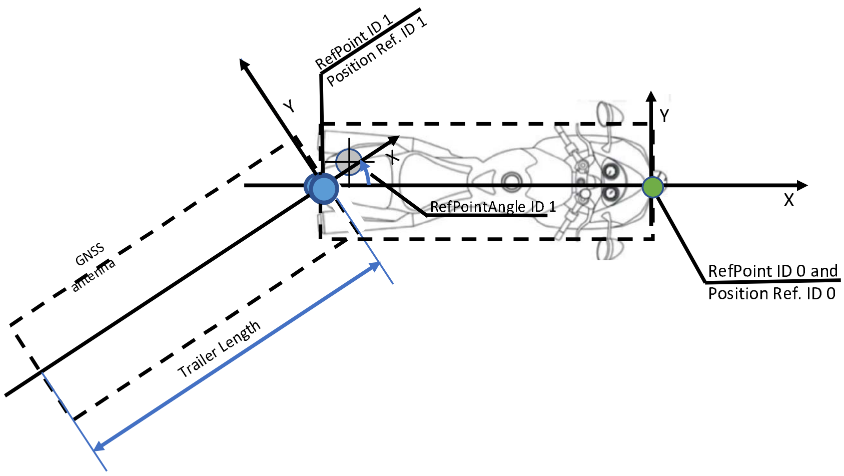

Figure 26: Motorcycle with trailer

6.2.6 ITS-S reference position for Pedestrians

The position of a pedestrian may be provided by their phone when configured as an ITS-S but also by a Road side detection system or in ITS-S equipment resided in any other road user equipment. Depending on the ITS-S sending information about the pedestrian, the system accuracy may vary resulting in varying accuracy confidences.

In any case the reference position of a single pedestrian shall refer to ground position at the center point of the face side of the pedestrian bounding box as depicted in Figure 27.

As the pedestrian density in a specific area may be significant, the transmission of pedestrian awareness information may have to be restricted. In such cases, information about recognized groups of pedestrians may be provided. A reference position for a group of pedestrians may be defined at a later stage.

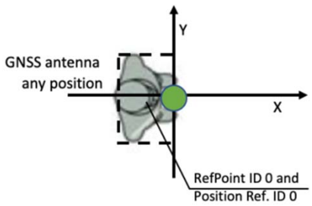

Figure 27: Pedestrian reference position

6.2.7 ITS-S reference position for Special Vehicles

At the moment no special Vehicles are defined. Special vehicles such as Agriculture vehicles may be considered in a future release of the present document.

6.2.8 ITS-S reference position for City-Tram

For city-trams, the ITS-S reference position shall refer to ground position at the center point of the front side of the bounding box of the city-tram (with regards to the forward driving direction). From the bounding box the mirrors and possible similar extensions as illustrated in Figure 28 are excluded. Mirrors and other extensions may be described by a separate bounding box and positioned relative to the reference position. As for the city-tram the forward driving direction depends on the location of the driver (at one moment the driver may be at the "Driver position 0" while a moment later the drive may control the city-tram from "Driving position 1", the ITS-S reference position will follow the driver and be at the other end of the city-tram when operated from that side independent of the location of the GNSS antenna.

In case the city-tram consists of several parts as depicted in the second model in Figure 28, the length of the city-tram is the length of the combination. Additionally, information may be provided about the HitchPointOffsets and RefPointAngles as depicted in Figure 28.

NOTE: In contrast to articulated busses, the length covers the complete trams, not only the first part.

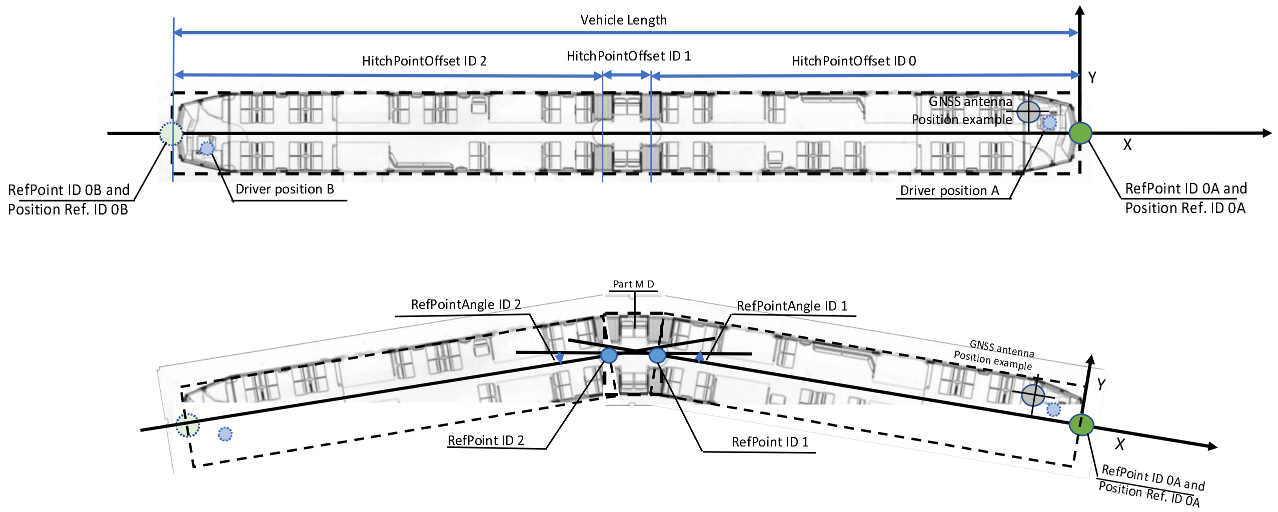

Figure 28: City-Tram reference position

6.2.9 ITS-S reference position for Roadside ITS Stations (R-ITS-Ss)

A Roadside Unit itself does not participate in traffic situations. It has therefore no functional but only a technical position. For technical reasons, however, the reference position shall be related to the physical location of the R-ITS-S. When an R-ITS-S provides services based on the transmission of position-based information, and has a single communication antenna, then the position at ground level of this antenna shall be used as a reference position.

NOTE: The R-ITS-S reference position may be used as reference for relative position information.

6.3 Position and time confidence

6.3.1 General requirements related to confidence

The PoTI entity may provide information on the accuracy of quantities it provides. The accuracy of a quantity is the closeness of agreement between the quantity and the true value (accepted reference value), see ISO 5725-1 [9]. In general, the accuracy is unknown, and needs to be estimated. This estimate shall include the systematic error (the trueness) and the random error (precision) of the specific quantity as specified in ISO 5725-1 [9].

Confidences of quantities provided by the PoTi entity shall be based on confidence values (for 1 dimensional quantities) or a confidence ellipse (for 2 dimensional quantities). A confidence value defines a (symmetric) confidence interval (see ISO 3534-1 [i.11], clause 1.28) given by the estimated value plus/minus the confidence value.

A confidence ellipse defines a confidence area, centered around the estimated value of a 2-dimensional quantity. A confidence ellipse is described via a major axis, minor axis and orientation of the major axis relative to a reference direction. A confidence level of X % means that the confidence interval or confidence ellipse would contain the true value of the quantity in a long series of measurements in at least X % of the measurements.

NOTE 1: In the Common Data Dictionary (ETSI TS 102 894-2 [10]) the confidence value is referred to as "confidence".

The confidences shall take into account the confidence of the information provided as input to the PoTi entity. If a position augmentation service is available, the confidence information of the augmentation service shall be taken into account as well.

As it is required that *at least* X % of the measurements would be contained in the confidence interval or ellipse, any interval or ellipse that completely encloses the provided interval or ellipse would also be a valid confidence interval or ellipse. In other word, any more conservative confidence would also be a valid confidence.

NOTE 2: In an operational system, the confidences will need to be estimated. This inherently means that the estimated confidence could be incorrect (i.e. too small). The likelihood that the estimated confidence is incorrect reduces when the estimate is made more conservative. However, if the estimate is made more conservative, this might leave the information provided by PoTi useless as the confidence could be use in the assessment to what extend the information can be used.

6.3.2 Confidences related to Position Information Management

6.3.2.1 Horizontal Position confidence

PoTi shall provide the horizontal position confidence for the reference position with a confidence level of 95 %. As specified in the Common Data Dictionary (ETSI TS 102 894-2 [10]), the horizontal position confidence shall be described using an ellipse shape, as illustrated in Figure 29. The ellipse is defined by its semiMajor and semiMinor axis, and the orientation of the semiMajor axis. The semiMajorOrientation, the orientation is defined by an angle with respect to WGS84 [6] North of the semimajor axis, counting clockwise, with a value between 0 degree and 360 degrees.

NOTE 1: To prevent fluctuation by 90 degrees of the orientation of the Axes, it is allowed that the semiMinor axis is actually larger than the semiMajor axis.

NOTE 2: None of the axis need to coincide with the heading of the vehicle, the orientation of the body of the vehicle, nor the coordinate system of WGS84 [6].

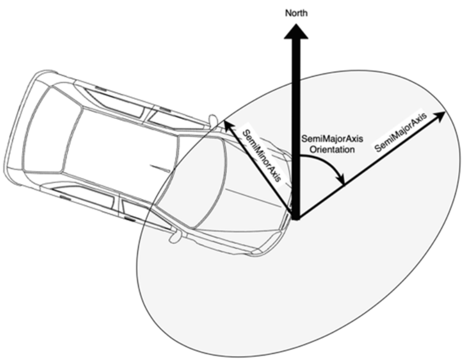

Figure 29: Representation of horizontal position confidence ellipse

6.3.2.2 Vertical Position confidence

PoTi shall provide a confidence value with a confidence level of 95 % for the vertical position of the reference position.

6.3.2.3 Horizontal Speed confidence

PoTi shall provide a confidence value with a confidence level of 95 % for the horizontal speed value.

NOTE: As horizontal speed is the length of a vector, it will always be greater or equal than 0 m/s. The defined confidence interval can have a lower limit smaller than 0 m/s, but that does not influence the definition; only the probability that the horizontal speed falls within the range below 0 m/s is 0.

6.3.2.4 Heading confidence

PoTi shall provide a confidence value with a confidence level of 95 % for the heading.

NOTE: As heading is the orientation of a vector, and ranges between 0 degrees and 360 degrees, the defined confidence interval need to be interpreted modules 360 degrees.

6.3.2.5 Confidence of other quantities

- If POTI provides additional quantities like acceleration, it may provide confidence information for these quantities. If it does, they shall have a confidence level of 95 %.

6.3.2.6 Other accuracy estimations

- POTI may provide additional accuracy estimations, e.g. Protection levels according to predefined confidence levels and integrity risks.

6.3.3 Confidences related to Reference Coordinate System Conversion Management

6.3.3.1 Relative Position confidence

The PoTi entity may provide relative position information. Relative position information is required e.g. for DeltaReferencePosition and calculations related to relevance areas. When calculating distances between absolute positions, the accuracy should be better than 0,55 %.

NOTE 1: A great-circle (or orthodromic) distance calculation method based on the haversine formula can be used to provide sufficient accuracy to meet this requirement.

NOTE 2: When calculating the confidence of relative positions, care need to be taken to treat correlated uncertainties appropriately.

6.3.4 Confidences related to Time Information Management

An ITS S shall maintain an estimate of the current ITS Time. The function providing this estimate is called the station clock and shall be used as the time reference for the PoTi entity. In practice, the station clock will have a deviation from ITS Time. The error of the station clock is defined as the absolute difference between ITS Time and the station clock. In general, the error can vary as a function of time. The absolute accuracy of a station clock is defined as the maximum of the station clock error. The maximum error shall be less than pPoTiMaxTimeDiff, i.e. For all t, |station clock time(t) - ITS time(t)| < pPoTiMaxTimeDiff.

NOTE 1: Only moments in time are considered when the ITS-S is active.

NOTE 2: Some implementations of an ITS-S could span across multiple ECUs and TCUs. In such case several physical clocks could exist. In such cases the above requirement applies to the system as a whole: any effects resulting from physical clock errors should not supersede the effect of a (single) station clock with the required absolute accuracy.

The pPoTiMaxTimeDiff value shall be 20 ms or less. Specific services can put more stringent demands on the absolute accuracy and shall require that in a service specific standard.

The accuracy of the station clock shall be taken into account when any of the other confidences in the PoTi are calculated. For example, the position confidence will be influenced by the accuracy of the station clock depending on the horizontal speed of the ITS-S.

7 Augmentation services

7.1 Introductions

Different kinds of GNSS based positioning methods are available and used for the Release 1 ITS applications and service (e.g. described in ETSI TS 103 246-1 [i.8]).

However, when considering at more advanced applications such as C-ACC, Platooning and Vulnerable Road User (VRU) applications, the more stringent position requirements can be barely or not at all be supported by basic GNSS implementations. Additionally, there are environmental situations in which even the Release 1 applications are not sufficiently supported e.g. in tunnels and urban canyons. To improve accuracy of the position and time estimates augmentation services may be used.

Currently the following augmentation service families requiring information exchange between ITS-Ss are recognized:

- GNSS Positioning Correction (GPC) augmentation service provides raw data for conventional D-GNSS, RTK, NRTK and PPP positioning methods as specified in clause 7.2.
- R-ITS-S ranging augmentation service as specified in clause 7.3.
- Cellular based positioning technologies which support or assist the calculation of the geographical position of a UE (User Equipment) by leveraging Radio Access Network (RAN) signals and protocols have been developed in 3GPP (3rd Generation Partnership Project). The cellular based positioning technologies ensure the improvement of the quality and continuity of PoTi services in certain situations where the satellite signal is unavailable. Even in other situations where the satellite signal is available, the cellular based positioning technologies can improve the quality and continuity of PoTi services as a complementary source to the GNSS based positioning techniques.
- LTE (Long-Term Evolution) based positioning technologies may be implemented as specified in ETSI TS 136 305 [i.12].

Besides the above mentioned methods, additional ones are being developed based on Ultra-Wide Band (UWB) techniques. UWB techniques may be especially useful for VRUs and in Tunnels and Urban Canyons. The data exchange service for these augmentation methods may be included in later version of the present document.

There various Wi-Fi™ related positioning techniques available are particularly useful in Wi-Fi™ dense covered areas. While the functionality of their link layer technology is similar to ITS-G5, their accuracy strongly varies and is usually not better than traditional GNSS solutions and therefor the information exchange for these methods are not considered in the present document.

While some items on the list above are by themselves not accurate enough for some C-ITS use cases, they contribute to realize higher accuracy, reliability and availability than stand-alone GNSS.

7.2 GNSS Positioning Correction (GPC) Augmentation Service

7.2.1 Introduction

The GNSS augmentation service described in clause 7.2 is explained with respect to V-ITS-S consuming the service and R-ITS-S offering the service and is easily generalized to any type of ITS-S.

Traditional GPC services implement cloud-based D-GNSS and/or RTK reference station functionality. The herein specified ITS service implements D-GNSS and/or RTK reference station functionality into R-ITS-S type ITS-S. Therefore, R-ITS-Ss are able to provide GPC service directly. The related new ITS-specific requirements are the following: support of high-speed (highway driving) scenarios at sufficient precision for automated driving use cases, support of positioning using different R-ITS-S areas (in a sequence or simultaneously), support of fast (within 1 to 2 seconds) recovery of GPC service after a communications outage.

According to this concept, the R-ITS-S behaves as a conventional D-GNSS and/or RTK reference station. The required reference station measurement data are provided through ITS-S RTCMEM messages in the ETSI TS 103 301 [1], over GeoBroadcast service. The details of such reference station functionality are described in (ETSI TS 103 246-1 [i.8], Annex A), The details of ITS-S container and RTCMEM message structure are given in the ETSI TS 103 301 [1]. The measurement data for GPC is geo-broadcast by the R-ITS-S to mobile ITS stations. From these broadcasted measurement data, ITS-Ss available to calculate the accurate position of the vehicle (up to centimeter level accuracy). The requirements of GPC service are presented in clause 7.2.2.

7.2.2 GPC requirements

Since the RTCM 104 standards (RTCM 10402.3 [2] and RTCM 10403.3 [3]) cover wide range of use cases for D-GNSS positioning techniques, additional requirements are necessary, which reflect the specific needs of the ITS system. The GPC service implementation shall maintain the RTCM data format as specified by the RTCM 10402.3 [2] and the RTCM 10403.3 [3], while the ITS-specific message format as defined in the ETSI TS 103 301 [1] shall be used.

The positioning accuracy and time-to-fix require frequent RTCM messages that carry observations, corrections and station coordinates. The periodicity of RTCM messages may technically vary between 1 second and 1 minute (depending on the message type), and it is determined by the GPC service provider. In accordance with current GNSS equipment capabilities and the above mentioned ITS specific requirements, the GPC service of the R-ITS-S shall send RTCM messages with 1 second periodicity. These messages include the RTCM message type 1005 that carries station coordinates. One of these message types is required to be broadcast by the GPC service of R-ITS-S at 1 second periodicity.

In the R-ITS-S, the station and/or antenna coordinates (depending on the RTCM message type) shall be determined accurately, preferably on centimeter level. The precise determination of distance between the mobile ITS Station and the R-ITS-S is one of the key requirements for accurate positioning by D-GNSS, RTK and NRTK techniques.

The GPC service of the R-ITS-S shall provide measurements data at 1 Hz periodicity, encapsulated into the V-ITS-S RTCMEM message as specified in the ETSI TS 103 301 [1]. One or more of the following message types shall be broadcast, depending on the R-ITS-S capabilities: RTCM 10403.3, RTCM 1077 [3] for GPS systems, RTCM 10403.3, RTCM 1087 [3] for GLONASS systems or RTCM 10403.3, RTCM 1097 [3] for Galileo systems. The R-ITS-Ss shall broadcast this message in their coverage area. Table 5 summarizes the required periodicity of RTCM message types.

Table 5: RTCM message type periodicity for GPC service

RTCM message type	Required periodicity for GPC service	Comments
RTCM3.2 - 1005	1 Hz	Contains R-ITS-S station coordinates
RTCM3.2 - 1077	1 Hz	GPS MSM7 auxiliary operation information, up to 904 bytes length
RTCM3.2 - 1087	1 Hz	GLONASS MSM7 auxiliary operation information, up to 904 bytes length
RTCM3.2 - 1097	1 Hz	GALILEO MSM7 auxiliary operation information, up to 904 bytes length

The accuracy of GNSS positioning shall not be affected when driving across the service boundary between subsequent GPC R-ITS-Ss. To meet this objective, further requirements are described in clause 7.2.3.

7.2.3 GPC Data processing by the V-ITS-S during transition between R-ITS-S service areas

This clause describes GPC data processing functions in the V-ITS-S, which ensure the avoidance of any position jitter while switching GPC service areas.

To avoid GNSS positioning errors which may be caused by simultaneous messages from different GPC services provided by different R-ITS-Ss, the GPC processing service of V-ITS-Ss shall select one GPC service as reference and shall pass RTCMEM messages originating only from this reference station to the GNSS positioning function. Such simultaneous reception of RTCMEM messages originating from different R-ITSs happens in overlapping GPC service areas, as shown in Figure 30. RTCMEM messages originating from other R-ITS-Ss GPC services may be buffered to minimize the time required for a GPC service area change.

The V-ITS-S shall manage the transition from one GPC service area to another GPC service area. When this occurs the V-ITS-S shall be able to detect the absence of the used GPC service and detect a GPC service from another R-ITS-S. By using the StationID field of the ITS header as reference, the V-ITS-S can detect GPC services as provided by R-ITS-Ss. The threshold value of waiting to be serviced by a GPC service of a R-ITS-S is 2 seconds. Upon the expiration of this waiting time, the V-ITS-S shall consider that the vehicle left the broadcast area of the originating GPC service and an GPC service provided by another R-ITS-S needs to be considered based on the existence RTCMEM message in the buffer. If several R-ITS-Ss' RTCMEM messages are present in the buffer, the V-ITS-S may select any of the available R-ITS-Ss as a new reference station. Subsequently, only RTCMEM messages originating from the newly selected R-ITS-S shall be processed.

If the selection of a new reference station is unsuccessful, i.e. no R-ITS-S is providing GPC service in the given area, the GNSS positioning function may select a different GPC service using for instance a cellular network connected based RTCM service. The reception of an RTCM 1005 message triggers the V-ITS-S to switch back to ITS based GPC service usage.

When a new reference station is selected, the V-ITS-S ensures that no old state information is retained from the previously used GPC service area.

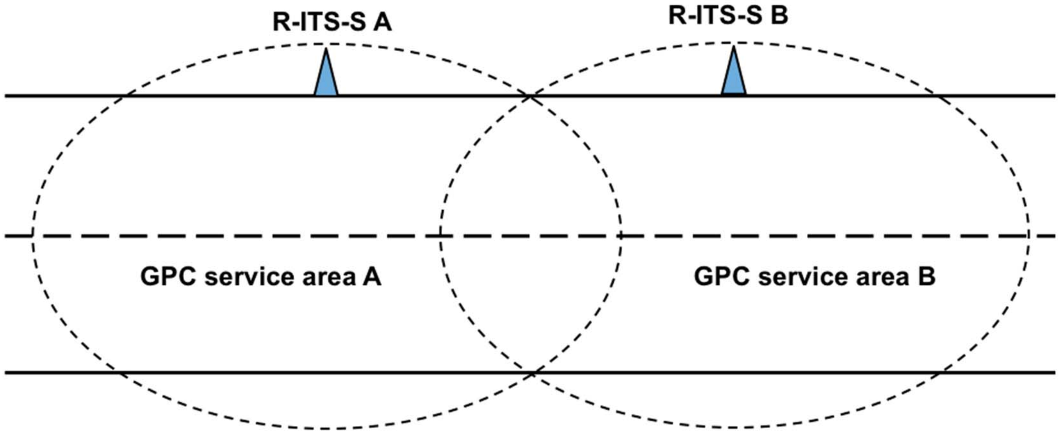

Figure 30: GPC services areas for full coverage scenario

7.3 R-ITS-S ranging augmentation Service

7.3.1 Introduction

The operation of ranging augmentation service within an ETSI ITS system is as follows:

- An R-ITS-S transmits its suitability for ranging by transmitting SAMs which advertise the Ranging Service availability.
- These R-ITS-S transmit relevant system information via:
  - The Ranging Application Data (`ITSRangingSAMData`) described in clause 7.3.2.
  - The `ThreeDLocation` field transmitted in the SAM (the installed location of the R-ITS-S antennas).
- An ITS-S (e.g. a V-ITS-S) transmit unicast data frames of zero length frame body (*ranging probes*) to R-ITS-S with which it wants to range, described in clause 7.3.3.
- These ranging probe frames are transmitted on the service channel (`ChannelIndex`) specified in the SAM message (more details in clause 7.3.3).

A message sequence diagram describing the above is shown in Figure 32.

The R-ITS-S Ranging service is advertised using ETSI SAMs as defined in ETSI EN 302 890-1 [5] using the ITS-AID as 0x20-40-9F (0pE0-00-00-1F) specified in the ITS Registry using SA port number as specified in ETSI TS 103 248 [8].

NOTE 1: The ITS-AID of the ranging service can be found in any official ITS-AID registry such as:

- https://standards.ieee.org/products-services/regauth/psid/public.html.

NOTE 2: The R-ITS-S Ranging service could also be advertised using service advertisement as specified in one of the profiles given in EN ISO 22418 [i.17], or IEEE 1609.3 [i.18].

These ranges can be fused with other positioning sensors such as GNSS as shown in Figure 31.

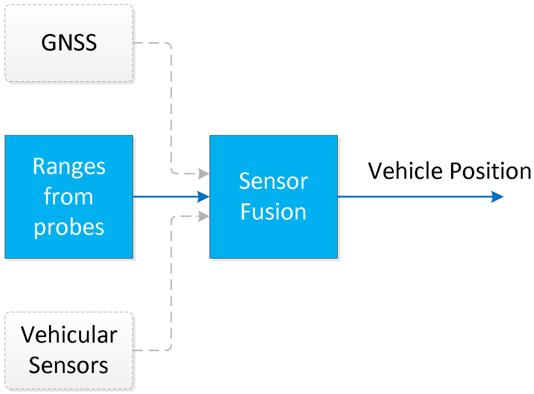

Figure 31: Fusion of positioning services

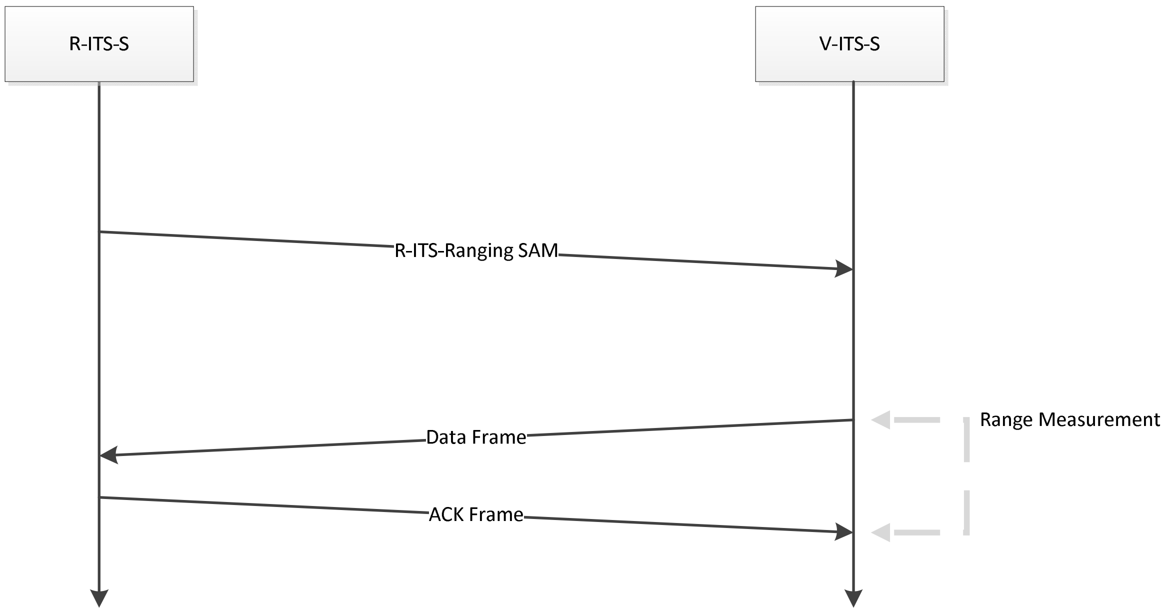

Figure 32: A typical message exchange sequence

7.3.2 Ranging service announcements

7.3.2.1 Introduction

By receiving a Service Announcement Message (SAMs) from an R-ITS-S announcing the ACK-Response time-based ranging service, an ITS-S identifies the availability of an R-ITS-S facilitating this ranging service. Such a SAM shall contain at least the following elements:

- 3D location of the R-ITS-S provided in the `ThreeDLocation` extension element specified in ISO/TS 16460 [12].
- A service field extension with a globally unique ITS-AID (PSID) as specified in the ITS-AID registry.

- The `SAMapplicationData` field set as outlined in clause 7.3.2.2.

NOTE 1: The ITS-AID registry can be found at:

  - https://standards.ieee.org/products-services/regauth/psid/public.html.

The service channel (`ChannelIndex`) and `ProviderMacAddress` could also be optionally specified (only if they are different to the one used in the SAM message).

NOTE 2: The accuracy of the advertised location of the (fixed reference) R-ITS-S is extremely important as any inaccuracy can lead to errors in estimated positions. Thus, it is highly recommended that `ThreeDLocation` of R-ITS-S is accurate to within 0,1 meter.

7.3.2.2 Ranging Service Application Data

Ranging Service Application Data (`ITSRangingSAMData`) shall be transmitted in the `SAMapplicationData` field of `ServiceInfoExt` of a SAM specified in e.g. ETSI EN 302-890-1 [5]. The details of the data elements are described in Table 6, Table 7, Table 8 and Table 9.

Table 6: Ranging Service Announcement Application Data

Field	Bytes	Description
Version	1	Version should be 1 for this release
ACK-Response Service	NA	Specified in Table 7
(Optional) Ground Altitude	NA	Specified in Table 8
(Optional) Road Angles	NA	Specified in Table 9

Table 7: ACK-Response Service

Field	Description
AckRespDelayAdjust	The site (and or vendor-specific) SIFS (see ETSI EN 302 663 [4]) turn-around response time delay adjustment from the nominal (32 µs), in 0,1 ns units. A signed number. This value specifies the processing delay with respect to the antenna of a device (thus includes the processing and RF cable length-based propagation delays).
AckRespDelayStdDev	The ACK response time standard deviation of the advertising ITS-S, in 0,1 ns units. An unsigned number.

Table 8: Ground Altitude

Field	Description
GroundAltitude	A.103 DF_Altitude from ETSI TS 102 894-2 [10] (CDD). Altitude of ground level related to the R-ITS.

Table 9: Road Angles

Field	Description
RoadAngles	List of road angles serviced by an R-ITS-S, unsigned 0,1 degree units from North. Each element is of type A.112 DF_Heading specified in ETSI TS 102 894-2 [10] (CDD). The road angle uncertainty is specified in the headingConfidence subfield. It is useful in situations where identification of orientation of the road coverage regions of a R-ITS is required.

An R-ITS-S providing the ACK-Response ranging service shall set `ACKResponseService` and may set `GroundAltitude` and `RoadAngles` elements in the `ITSRangingSAMData`. The ASN.1 specification in Annex A shall be used. For the encoding of the `ITSRangingSAMData` the UPER encoding scheme as specified in Recommendation ITU-T X.691 [13] shall be used. This UPER encoded `ITSRangingSAMData` become the octets of the `SAMapplicationData` field of `ServiceInfoExt` of a SAM specified in e.g. ETSI EN 302-890-1 [5].

7.3.3 Measurement

A ranging measurement to an R-ITS-S is made by sending a unicast MAC PDU (of type Data) with a zero length Frame Body (called a *ranging probe*) from an ITS-S to the R-ITS-S. The R-ITS-S MAC layer shall respond with an ACK frame (as per ETSI EN 302 663 [4]) enabling a radio communication air-propagation Time-of-Flight (ToF) measurement. This ToF measurement may be used to estimate distance (range) between ITS-S and R-ITS-S. An ITS-S can send *ranging probes* to an R-ITS-S advertising a valid Ranging Service (with the `ACKResponseService` element present). This message sequence is shown in Figure 32. It is recommended that *ranging probes* use lowest priority AC_BK for QoS as described in clause C.4.4 of ETSI EN 302 663 [4].

The ranging probes shall be transmitted by an ITS-S to an advertising R-ITS-S using the channel identified in the `ChannelInfos` component indexed by the `ChannelIndex` component of the service info component (i.e. as per clause 5.2 of ETSI EN 302 890-1 [5]). If this is not specified, then the same channel on which the advertisement was received shall be used.

The ranging probes shall be transmitted by the ITS-S to an advertising R-ITS-S using the destination `MACaddress` identified by the `ProviderMacAddress` component of the service info component. If this is not specified, then the same `MACaddress` on which the advertisement was received shall be used.

The ranging ITS-S can adjust the range as per the parameters specified in the ACK-Response Service. It can add the `AckRespDelayAdjust` to remove the processing and cable length-based delays from the propagation (ToF) delay. The timing accuracy and qualification of the R-ITS-S is not in scope of the present document.

7.3.4 Ranging Rate

The rate at which a V-ITS-S sends ranging probes to an R-ITS-S is determined by the vehicle's horizontal speed. Effectively the number of ranging probes per meter travel distance of a vehicle is kept at a constant. When the vehicle is stationary the ranging rate is minimum and could be zero. A V-ITS-S shall transmit no more than 1 ranging probe frame in any 50 ms period to an R-ITS-S.

7.3.5 Security

Only those R-ITS-S which transmit signed R-ITS-Ranging SAMs and have had their authenticity verified shall be used for ranging by an ITS-S.

Annex A (normative): ASN.1 specification of messages

A.1 ASN.1 specification of ranging service application data

```
ITSRangingSAMData { itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) en (302890)
poti (2) version (1) }

DEFINITIONS AUTOMATIC TAGS ::=

BEGIN

IMPORTS
Altitude, Heading FROM ITS-Container { itu-t (0) identified-organization (4) etsi (0) itsDomain (5)
wg1 (1) ts(102894) cdd (2) version (2) };

ITSRangingSAMAppData ::= SEQUENCE {
    protocolVersion INTEGER (0..255),
    ackResponseService ACKResponseService,
    groundAltitude Altitude OPTIONAL,
    roadAngles RoadAngles OPTIONAL,
    ...
}
ACKResponseService::= SEQUENCE {
    ackRespDelayAdjust INTEGER (-32768..32767),
    ackRespDelayStdDev INTEGER (0..65535),
    ...
}
RoadAngles::= SEQUENCE OF Heading
END
```

History

Document history				
V2.1.1	March 2020	EN Approval Procedure	AP 20200628:	2020-03-30 to 2020-06-29
V2.1.1	August 2020	Vote	V 20201019:	2020-08-20 to 2020-10-19