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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

The present document is part 1 of a multi-part deliverable covering the GNSS based location systems, as identified below:

Part 1: "Functional requirements";

Part 2: "Reference Architecture"

Part 3: "Performance requirements";

Part 4: "Requirements for location data exchange protocols";

Part 5: "Performance test specification".

Introduction

The increasing proliferation of location-based services is based on several trends in user applications and devices; these include notably the widespread adoption of multi-functional smart-phones etc., and the wider adoption of tracking devices (e.g. in transport). This need for new and innovative location-based services is generating a need for increasingly complex location systems. These systems are designed to deliver location-related data for one or more location targets to user applications.

The wide spectrum of technical features identified in [i.1] calls for a new and broader concept for location systems, taking into account hybrid solutions in which GNSS technologies are complemented with other technology sensors to improve robustness and the performance.

Hence a set of standards for GNSS-based location systems is defined, of which the present document is part 1.

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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1 Scope

The present document addresses integrated location systems that combine Global Navigation Satellite Systems (GNSS), with other navigation technologies, as well as with telecommunication networks in order to deliver location-based services to users.

The requirements herein are intended to address the growing use of complex location systems needed for the provision of location-based applications particularly for the mass-market (refer to [i.1]).

The present document defines the functional requirements applicable to location systems, based on a synthesis of types of applications relying on location-related data provided by location system.

The present document can be considered as the Stage 1 characterization of location systems according to the ITU/3GPP approach [i.2].

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 reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://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.

Not applicable.

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 reference 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 TR 103 183: "Satellite Earth Stations and Systems (SES); Global Navigation Satellite Systems (GNSS) based applications and standardisation needs".

[i.2] Recommendation ITU-T I.130: "Method for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN".

[i.3] IS-GPS-200: "Revision D, Navstar GPS Space Segment/Navigation User Interfaces".

[i.4] IS-GPS-705: "Navstar GPS Space Segment/User Segment L5 Interfaces".

[i.5] IS-GPS-800: "Navstar GPS Space Segment/User Segment L1C Interfaces".

[i.6] European GNSS (Galileo) Open Service: "Signal In Space Interface Control Document", Issue 1.1.

[i.7] "Global Navigation Satellite System GLONASS Interface Control Document", Version 5.1.

[i.8] DTFA01-96-C-00025: "Specification for the Wide Area Augmentation System (WAAS)", US Department of Transportation, Federal Aviation Administration.

[i.9] RTCA DO-229D: "Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment", SBAS ICD Annex 1.

[i.10] IS-QZSS, Quasi Zenith Satellite System Navigation Service Interface Specifications for QZSS, Ver.1.0.

[i.11] BDS-SIS-ICD-B1I-1.0: "BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal B1I (Version 1.0)".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document the following terms and definitions apply:

application module: entity in charge of retrieving from a *location system* the *location-related data* associated to one or more *location targets* and processing it in order to deliver to the application user the *location based service* it has been designed for

NOTE: The application module can be located inside or outside a terminal.

authentication: provision of assurance that the location-related data associated with a location target has been derived from real signals associated with the location target

NOTE: By extension, authentication is one of the key performance features that can be required to a location system.

architecture: abstract representation of a communications system

NOTE: Three complementary types of architecture are defined:

- Functional Architecture: the discrete functional elements of the system and the associated logical interfaces.
- Physical (Network) Architecture: the discrete physical (network) elements of the system and the associated physical interfaces.
- Protocol Architecture: the protocol stacks involved in the operation of the system and the associated peering relationships.

availability: measures percentage of time when a *location system* is able to provide the required *location-related data*.

NOTE: The required *location-related data* might vary between *location based applications*. It may not only contain a required type of information (e.g. position and speed), but also a required *quality of service* (e.g. accuracy, protection level, authentication).

continuity: likelihood that the navigation signal-in-space supports the accuracy and integrity requirements for the duration of the intended operation

NOTE: It guarantees that a user can start an operation during a given exposure period without an interruption of this operation, assuming that the service was available at beginning of the operation. Conversely, a *Loss of Continuity* occurs when the user is forced to abort an operation during a specified time interval after it has begun (the system predicts service was available at start of operation).

continuity risk: probability that a detected but unscheduled navigation interruption after initiation of an operation

electromagnetic interference: any source of RF transmission that is within the frequency band used by a communication link, which degrades the performance of this link

NOTE: *Jamming* is a particular case of electromagnetic interference, where interfering radio signal is deliberately broadcast to disrupt the communication.

fraud: any kind of activity of a location-based application stakeholder aiming at jeopardizing the application objective.

NOTE: By extension, it describes the activity aiming at reporting a falsified location target position in the frame of location-based applications.

integrity: function of a *location system* that measures the trust that can be placed in the accuracy of the *location-related data* provided by the *location system*

NOTE: In the present technical context, it is expressed through the computation of a *protection level*. The *Integrity* function includes the ability of the location system to provide timely and valid warnings to users when the system should not be used for the intended operation. Specifically, a location system is required to deliver a warning (an *alert*) of any malfunction (as a result of a set alert limit being exceeded) to users within a given period of time (*time-to-alert*). Related to the *Integrity concept*, a Loss of Integrity event occurs when an unsafe condition occurs without annunciation for a time longer than the time-to-alert limit.

integrity risk: probability that the *actual error* of the *location-related data* is larger than the *protection level*, in case of system availability (i.e. protection level lower than the alert limit)

jamming: deliberate transmission of interference in order to disrupt communications

NOTE: In the present technical context, targeted communication signals are GNSS or telecommunication signals.

latency: latency of a location system measures the time elapsed between the event triggering the determination of the *location-related data* for (a) *location target*(s) (i.e. location request from external client, external or internal event triggering location reporting), and the availability of the *location-related data* at the user interface

location-based application: application that is able to deliver a *location-based service* to one or several users

location-based service: service built on the processing of the *Location-related data* associated with one or several *location targets*

location-related data: set of data associated with a given *location target*, containing one or several of the following time-tagged information elements: target position, target motion indicators (velocity and acceleration), and Quality of service indicators (estimates of the position accuracy, reliability or authenticity)

NOTE: It is the main output of a *Location system*.

location system: system responsible for providing to a *location based application* the *Location-related data* of one or several location targets

location system central facility: centralized logical entity, inside a *Location system*, that manages the communication of the *location-related data* to the *application module*, which is the location system external client

location target: physical entity on whose position the *location system* builds the *location-related data*

NOTE: This entity may be mobile or stationary.

positioning module: logical entity inside a *Location system* responsible for providing the relevant measurements to the *location system central facility* (enabling it to determine the *location target location-related data*) or directly providing the *location target location-related data* to the *Application module*

NOTE 1: It is composed of a GNSS receiver and possibly additional sensors.

NOTE 2: The positioning module executes the measurements needed to determine its position, and implements part of the location determination functions. It embeds the group of sensors needed to execute these tasks. This group can include navigation sensors (GNSS, terrestrial beacons, Inertial, Odometers, etc.) It might be collocated with the *location target* or not.

privacy: function of a *location system* that aims at ensuring that the location target user private information (identity, bank accounts, etc.) and its *location-related data* cannot be accessed by a non-authorized third party

Protection Level (PL): upper bound to the position error such that: $P(\varepsilon > PL) < I_{risk}$, where I_{risk} is the *Integrity risk* and ε is the *actual position error*

NOTE: The *protection level* is provided by the location system, and with the integrity risk, is one of the two sub-features of the *integrity* system. The protection level is computed both in the vertical and in the horizontal position domain and it is based on conservative assumptions that can be made on the properties of the GNSS sensor measurements, i.e. the measurement error can be bounded by a statistical model and the probability of multiple simultaneous measurement errors can be neglected.

pseudorange: pseudo distance between a satellite and a navigation receiver computed by multiplying the propagation delay determined by the receiver with the speed of light

NOTE: The prefix "pseudo" highlights the fact that the propagation delay accessible to the receiver encompasses contributors (such as receiver local clock offset with respect to satellite time) which does not allow it to determine the actual geometrical distance.

Pseudo-Random Noise code (PRN): unique binary code (or bit sequence) transmitted by a GNSS satellite to allow a receiver to determine the travel time of the radio signal from satellite to receiver, and to distinguish the different visible satellites

Quality of service: associated with a location-based service is a set of indicators that can accompany the *location target*'s position/motion information and is intended to reflect the quality of the information provided by the *location system*

NOTE: QoS indicators can be an *accuracy* estimate, a *protection level* statistic, *integrity risk*, authentication flag.

security: function of a *location system* that aims at ensuring that the *location-related data* is safeguarded against unapproved disclosure or usage inside or outside the *location system*, and that it is also provided in a secure and reliable manner that ensures it is neither lost nor corrupted

spoofing: transmission of signals intended to deceive location processing into reporting false target data

time-to-alert: time from when an unsafe integrity condition occurs to when an alerting message reaches the user

Time to First Fix: refers to the time needed by the receiver to perform the first position and time fix whose accuracy is lower than a defined accuracy limit, starting from the moment it is switched on.

Vertical axis: axis locally defined for the location target, collinear to the zenith/nadir axis.

3.2 Symbols

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

φ	Carrier phase
εAccel	Error on sensor acceleration (from INS)
εAtt	Error on sensor attitude (from INS)
εGyro	Error on sensor gyroscopes (from INS)
εPos	Error on sensor position (from INS)
εPos_{3D}	Uncertainty on sensor position (from GNSS)
εV	Error on sensor attitude (from INS)
εV_{3D}	Uncertainty on sensor speed (from GNSS)
d	Carrier Doppler
P_{GNSS}	Position estimate coming from GNSS sensor
P_{INS}	Position estimate coming from the INS
V_{GNSS}	Speed estimate coming from GNSS sensor
V_{INS}	Speed estimate coming from the INS

3.3 Abbreviations

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

3GPP	3rd Generation Partnership Project
ADAS	Advanced Driver Assistance Systems

A-GNSS	Assisted GNSS
D-GNSS	Differential GNSS
E-CID	Enhanced Cell-ID
EGNOS	European Geostationary Navigation Overlay System
E-OTD	Enhanced Observed Time Different
GAGAN	GPS-Aided Geo-Augmented Navigation
GBLS	GNSS-Based Location Systems
GEO	Geostationary Earth Orbit
GLONASS	Global Navigation Satellite System (Russian based system)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile communications
INS	Inertial Navigation Sensor
IT	Information Technology
ITS	Intelligent Transport Systems
LBS	Location Based Services
LTE	Long Term Evolution
MMI	Man-Machine Interface
MNO	Mobile Network Operator
MSAS	Multi-functional Satellite Augmentation System
OBU	On-Board Unit
OTDOA	Observed Time Difference Of Arrival
PAYD	Pay As You Drive
PL	Protection Level
PRN	Pseudo-Random Noise code
QoS	Quality of Service
QZSS	Quasi-Zenith Satellite System
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
RTK	Real Time Kinematic
SBAS	Satellite Based Augmentation System
SCN	Satellite Communications and Navigation (Working Group of TC-SES)
SNR	Signal to Noise Ratio
UMTS	Universal Mobile Telecommunications System
UTDOA	Uplink Time Difference of Arrival
WAAS	Wide Area Augmentation System

4 Context description

4.1 Location based applications needs

4.1.1 Reminder on ETSI TR 103 183 content

ETSI TR 103 183 [i.1] provides a thorough inventory of the location based applications, which is used as a reference in the present document. The present clause reminds the classification work which was conducted in order to identify the applications driving needs.

These needs were organized in two separate categories:

- Needs common to all location-based applications, because they correspond to fundamental expectations independently from the specifities of the different considered applications,
- Additional specific needs, arisen from constraints imposed by applications specificities.

4.1.2 Common needs

In order to describe needs common to all location-based applications, the definition of location based service already given in clause 3.1 is further developed below.

Location-Based Services (LBS) are IT services built upon location-related data (position, heading, speed, etc.) associated to one or several location targets, and delivered to one or several external end-users. Example is given in table 4-1. The value of such services stands in the fact that:

- location-related data of location targets is a priori not known;
- services remain available over a predefined service area.

A location-based application is in charge of implementing a location-based service. As such, it shall comply with the following needs:

- the application shall enable the provision of the location-based service to one or **multiple end users**;
- the application shall enable the provision of the location-based service related to one or **multiple location targets**;
- the application shall implement mechanisms allowing to enforce **service policy**, such as:
  - **privacy protection policy**, in order to protect the location target user identity (where relevant);
  - **data protection policy**, in order to control access to information identified as sensitive (through confidentiality, authentication and integrity mechanisms);
- the application shall enable provision of location-based services related to location target(s) with **a priori unknown location-related data**;
- the application shall enable provision of location based services when location target(s) is (are) disseminated within an arbitrarily **wide area**.

4.1.3 Specific needs

Application classes were established in ETSI TR 103 183 [i.1] by gathering location-based applications having the same differentiating need(s). An inventory of these needs is reminded below, in order to list the needs specific to a subset of applications.

- **Location Based Charging**

  The objective is to charge a user based on its reported position. The main driving needs are:

  - **Reliability of check point crossing detection:** there is a risk that user reported position triggers a charging event whereas it is actually in a position free of charge.
    This risk is generally required to be very low.
  - **The service availability:** the percentage of cases when user actual position has to trigger charging event, but system is not properly informed. The service unavailability can be due either to an erroneous reported position, or to the unavailability of the location information itself.
    This service unavailability is generally needed to be low.

NOTE 1: This type of location-related requirement is needed for road user charging (road), on-street parking fee pricing (road), waterways and harbours charging (maritime/multimodal), home zone billing, regulated fleets in urban areas, etc.

- **"Pay As You Drive" (PAYD) charging**

  The objective is to charge a user based on the travelled distance (e.g. applicable for pay-per-use insurance). The challenge is quite similar to the previous group, except that useful information is rather the travelled distance than the position itself.

  The main driver is the **representativity of the travelled trajectory or distance** in order to globally optimise the fee collection.

NOTE 2: This type of location-related requirement is needed for pay-per-use insurance (road), car rental pricing (road), taxi service pricing (road), freight tolling (road), car-pooling (road), pay-as-you-pollute (road), energy charging (train).

- **Cooperative basic geo-localization**

  The objective is to recover the position of one or several assets or vehicle, remotely or not. The main drivers are generally:

  - **The reported position accuracy:** as far as fleet management or personal navigation is concerned, the main objective is to obtain an accurate position estimate.
    The required accuracy highly depends on the application: tens of meters for personal road navigation and vehicle fleet management, meters for pedestrian personal navigation and city sightseeing.
  - The **service availability:** position availability might not be as driving as for other application (see location based charging applications), but it is a clear challenge in the considered applications: car positioning in urban area (including high masking or shadowing, tunnel, important multipath) clearly suffers from degraded availability.

NOTE 3: This type of location-related requirement is needed for fleet/asset/resource management, personal navigation (pedestrian, road, multi-modal), traffic travel info, city sightseeing, etc.

- **Non-cooperative geo-localization**

  This class of application encompasses applications for which one or several stakeholders (target itself, target user, external actor) have an interest in fooling the application enabler by intentionally altering the location target position.

  The driver specific to this application class is the ability to **detect fraud,** by determining the authenticity of the location-related data.

NOTE 4: This type of location-related requirement is needed for some kind of fleet management (car rental), car recovery after theft (road), city logistics (road), house arrest (multi-modal).

- **Reliable geo-localization**

  The common objective among this class of application is to obtain a reliable position estimate for security, safety or legal reasons. Such applications are often referred to as "liability-critical applications".

  The main driver here is the reliability of the applicative figure of merit, which is dependent on the ability to **monitor the positioning performance** with a usually high confidence level. The concerned performances are typically the target position error (horizontal or vertical), trajectory error (along track, cross track) or time synchronization error.

  Each such application has its own tolerance regarding positioning performance. Thus, a properly monitored performance exceeding the application tolerance causes service unavailability. Therefore, the **reported position accuracy** is also an important driver.

NOTE 5: Both "non-cooperative geo-localization " and "reliable geo-localization " above rely on an assessment of the confidence associated to the target position-related data. They are however treated separately:

  - "Non-cooperative geo-localization" class only faces intentional position alteration aiming at luring the location based application. Any position uncertainty due to non-intentional origins (GNSS signal interference, multipath) are not covered.
  - "Reliable geo-localization" class however covers all sources of position alteration, in order to bring confidence in both position authenticity and accuracy.

NOTE 6: This type of location-related requirement is needed for livestock transport tracking and tracing survey, dangerous and hazardous cargoes tracking and tracing survey, special (high value, sensitive, dual) goods traffic tracking, perishable goods/food tracking and tracing.

- **(Reliable) Vehicle movement sensing**

  Some applications aim at collecting, in addition to the terminal position and/or trajectory, information related to its movement: speed, acceleration, heading, gyration, etc.

  The main driver is the **movement caption accuracy** (e.g. monitor a vehicles speed**)**.

As previously mentioned, the ability to **monitor the positioning performance** (here positioning refers to movement sensing) with a usually high confidence level might also be needed (e.g. for legal speed enforcement).

NOTE 7: This type of location-related requirement is needed for:

- Liability critical applications: legal speed enforcement (road), accident reconstruction (road), vehicle control assistance (ADAS) + collision warning (road), cold movement detector (train), traffic management systems (train).
- Non-liability critical applications: eco-driving and carbon emissions foot- printing (road), traffic congestion reporting (road).

4.2 Generic location-based application use case

Location-based applications are provided to identified end-user(s) by a dedicated provisioning system.

Such provisioning system relies on two major components: the **location system**, in charge of elaborating the location-related data upon which the value added service is built, and one or several instances of the **application module**, in charge of building the value-added service upon the location-related data received from the location system.

Figure 4-1 provides a generic and high level description of such provisioning system relying on GNSS-based location system.

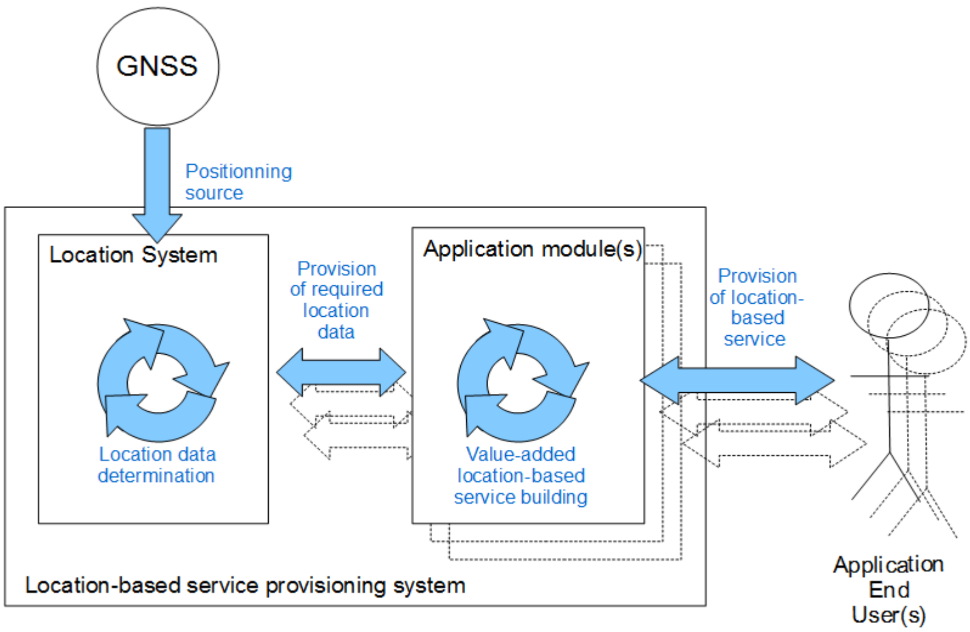

Figure 4-1: Location-based service context for GNSS-based location systems

The location-based service provisioning system may support a wide range of application end-user profiles: in field users, headquarter users, supervisors, etc. in fixed or mobile usage conditions.

The picture does not preclude any communication network architecture supporting the different logical interfaces identified.

In addition, the location-based service provisioning system implements a location system and at least one application module.

Table 4-1 maps the above generic description to the different cases of location-based application, all extracted from the inventory made in [i.1] and summarized in clause 4.1 above.

Table 4-1: Example of location-based applications

Application	End user	Location Target(s)	Location system	Application module	Value added service
Road charging	State/ Ministries of transports	Road Users Vehicles	Fleet of On-Board Units, equipped with positioning module and communication means, distributed over the targeted road users	Billing server collecting OBU/vehicles positions and deriving billing information	Possibility to apply road charges with limited infrastructure (i.e. off motorways).
Vehicle or pedestrian navigation	Vehicle driver or pedestrian	Vehicle or pedestrian itself	Positioning module (using GNSS, inertial and odometer measurements)	Navigation application, imbedded with the positioning module in a navigation terminal, providing guidance information to driver/pedestrian	Ability to provide to user its position, surrounding point of interest and travel directions
Precision farming	Farmers	Farming vehicles	Local RTK solution, composed of a reference station and one or several positioning modules installed on the targets	Harvest scheduling application, or farming vehicles automation application	Farming logistics optimization, Or 24/7 unmanned harvesting
Ride sharing	Car sharing aficionados	Shared cars	Fleet of On-Board Units, equipped with positioning module and communications means, distributed over participating cars	Centralized Car sharing application collecting OBU positions and building appropriate scheduling	Simple and efficient car sharing
Transaction synchronization	Trading company	Synchronization module	GNSS sensors restituting GNSS time for synchronization across wide areas	Stock exchange trading application, using restituted GNSS time as source of synchronization.	Accurate synchronization of trade orders
House arrest monitoring	Penitentiary authorities	Prisoner under house arrest	Monitoring wristlet, reporting position when prisoner steps out of constrained area	Central server collecting alarms reported by wristlets	Geo-fencing. House arrest remote monitoring means
Cellular Communication infrastructure monitoring	Mobile Network Operator	Potential sources of interference	Monitoring center aggregating information from GNSS receivers localized on the network base stations	Visualization application in MNO operation room	Improvement of network performance through identification of interference sources
Race monitoring and safety system	Race competitor and Race coordinator	Race vehicles (car, trucks, motorcycles)	Fleet of terminals, equipped with positioning module and communication means, distributed over the race vehicles and Central location server, achieving terminal M&C	MMI offered to race competitors (distress call trigger) and Application offered to race coordinator in headquarters, for monitoring purposes	Competitor position quasi real-time monitoring, distress call enabler

4.3 GNSS-based location systems

The present document provides the functional requirements applicable to GNSS-Based Location Systems (GBLS).

GBLS are defined as Location Systems using GNSS as a primary source of positioning. Hence, a GBLS shall support at least one of the GNSS methods listed in clause A.1. Optionally, it may support one or several of the following common positioning methods:

- assisted GNSS method, further described in clause A.2;
- Proximity sensing, further described in clause A.3;

- Multilateration, further described in clause A.4;
- Triangulation, further described in clause A.5;
- multi-sensor positioning through (A-)GNSS hybridization, further described in clause A.6;

In the rest of the present document, the terms location systems and GNSS-Based Location Systems are both used to refer to GBLS.

5 Functional requirements for Location system

5.1 Functional requirements outline

The following clauses provide the functional requirements applicable to the GBLS. These requirements are derived from location based application needs inventoried in clause 4.1 above.

An outline of the derivation strategy is given within this section, and summarized in Annex B (mapping between location based applications needs (common and specific) and GBLS functional requirements).

NOTE: This derivation strategy, also called functional analysis, is given for information only, since beyond the perimeter of the GBLS Technical Specifications.

Functional requirements are organized as follows :

- a set of mandatory requirements, which provide the specification any GBLS shall comply with, regardless of the type of application served. These requirements are derived from location based applications common needs given in clause 4.1.1 above.
- a set of optional requirements, arisen from the specificities of some of the targeted application classes. These requirements are derived from location based applications "specific needs" given in clause 4.1.2 above.

For each requirement, introductory words are given to identify the requirement origin.

Requirement itself is then worded and highlighted using the present formatting.

5.2 Mandatory requirements

5.2.1 Positioning techniques

The following mandatory requirements are applicable to any GBLS.

In order to support the application need to enable LBS provision over a wide variety of potential service area (in terms of characteristics such as size, location, obstacle density), it is mandatory that GBLS uses a GNSS positioning technique as the main source of location-related data. It indeed offers the best technical trade off matching the service area coverage need.

The GBLS shall provide location-related data containing at least the location-target geographical position, expressed in an explicit coordinate reference system, and the timestamp this position was sampled at, expressed in explicit reference timescale.

The GBLS shall determine the location-related data of the location target(s) through the use of at least one of the GNSS methods listed in clause A.1.

5.2.2 Location-related data delivery

The following mandatory requirements are applicable to any GBLS.

In order to support the application need to deliver LBS to end-users, it is expected that the GBLS is not only able to deliver the location-related data through a dedicated interface to an external entity (i.e. the application module), but also that the location-related data delivery can be monitored and controlled by this external entity.

The GBLS shall implement an external interface conveying location-related data, and allowing to monitor and control the data provisioning.

Furthermore, in case where application serves multiple end users, the supporting GBLS is expected to be able to process the incoming positioning requests based on a priority criteria. This is required in order to cope with the situation where the LBS delivery to several end users by the application requires the sending of simultaneous positioning requests to the GBLS.

The GBLS shall be able to handle the incoming positioning requests based on a priority criteria.

5.2.3 Location system policies

The following mandatory requirements are applicable to any GBLS.

For the majority of applications, location targets are owned by location targets users, whose private information, including identity and location-related data, needs to be protected. GBLS, as the component elaborating and delivering the location-related data is therefore expected to implement appropriate protection mechanisms. These mechanisms shall ensure that target location-related data is delivered to external entity (application module) only upon location target user authorisation. Several such mechanisms exist: management of a user privacy profile in GBLS, request for authorization of the user to authorise positioning operation (manual or conditional authorization).

The GBLS shall implement a privacy protection policy for the location target user, in order to ensure that location-related data delivery takes place upon authorization.

In order to properly support multiple LBS end users, GBLS shall be able to interface with multiple application modules. Therefore, when receiving positioning operation requests from application modules, the GBLS is required to implement a service authorization policy, so as to discriminate between authorized and unauthorized application modules.

The GBLS shall implement a service authorization policy in order to identify the application modules authorized to send it positioning requests.

Protection of sensitive information (i.e. with legal value, market value, defence value) at application level needs to be partially allocated to the GBLS. Indeed, a number of information contained in the GBLS (such as location-related data, location target identity) can be identified as sensitive information. As such, it needs to be protected against unwanted disclosure or alteration.

The GBLS shall implement security policy enabling the protection of sensitive information against unwanted disclosure or alteration.

5.3 Optional requirements

5.3.1 Positioning techniques

The following optional requirements might be applicable to GBLS.

In order to cope with some of the specific needs identified in clause 4.1.2, a state of the art review of technical solutions shows that combining GNSS technique as a primary source of positioning, with additional measurements provided by additional sensors, is a way to improve the positioning experience. As a consequence, considering the possibility to imbed in the GBLS additional sources of navigation, and implementing measurement fusion techniques, are proposed as an option.

The GBLS might use multiple sensors in order to collect additional measurements as a complement to the GNSS measurement source. In addition, it might implement hybridization techniques in order to enable the generation of consolidated location-related data.

5.3.2 Location-related data content

A number of the considered applications foresees the need for location target movement indicators, in addition to their position. It mainly concerns target speed and acceleration, heading, angular speed and angular acceleration. Some of this information can be reconstructed at application module level, based on the position alone. However, in case significant reliability of these indicators is sought, GBLS might be required to determine and output these data, using sensor measurements.

The GBLS might provide location-related data containing, in addition to the location-target geographical position and associated timestamp, one or several of the following information : location target speed, acceleration, heading, angular speed and angular acceleration.

In some applications, the type of service delivered requires the ability to monitor the positioning performance. This flows down to the GBLS as the necessity to be able to determine quality of service indicators. Different QoS indicators might be required depending on how demanding the application context is:

- Estimation of the position accuracy (horizontal or vertical). This indicator statistically characterizes the positioning error distribution, such as error standard deviation or percentile values.
- Horizontal or vertical protection level associated to a predefined - generally high - confidence level. This indicator is an upper bound of the actual positioning error distribution, and the reliability of this upper bound (i.e. risk of being exceeded by the actual positioning error) shall meet the required confidence level expressed as a probability (i.e. this risk shall be lower than the confidence level). On the contrary of the "position accuracy" QoS indicator, the protection level shall quantify and guarantee its bounding property.
- GNSS-based position authenticity flag. This indicator is the level of assurance that the location-related data for a location target has been derived from real GNSS signals relating to the target. In other words, it indicates if the information provided is a genuine position, or if it has likely been spoofed.

The GBLS might provide location-related data containing, in addition to the location-target geographical position and associated timestamp, one or several of the following quality of service indicators : location target position accuracy (horizontal or vertical), protection level (horizontal or vertical), and authenticity flag.

5.3.3 Location-related data delivery

The availability of the LBS has been identified as a driving performance for some applications. As a major contributor to the service provision, GBLS itself might therefore be required to be able to provide location-related data to the application module in specified percentage of time (also called availability). This ability mainly depends on three GBLS performances:

- System availability, which is the percentage of time the GBLS itself (hardware and software components) is available, i.e. operational. It takes into usual system "Reliability, Availability and Maintainability" considerations.
- GBLS Response latency, which the time elapsed between reception of the positioning request from the application module and provision of the associated answer. This latency is driven by the time taken to conduct positioning operations, including location target position determination through sensor measurements, and in case of a distributed system the performance of the communication channel.
- GBLS coverage, which represents the area the location target can travel across and still be positioned. It therefore depends on the type of positioning techniques used, the type of environment locally met, and in case of a distributed system the performance of the communication channel.

The GBLS might be required to meet a pre-defined availability performance of its hardware and software components.

The GBLS might be required to meet a pre-defined latency in the location-related data reporting to the application module.

The GBLS might be required to provide position-related data when location target target(s) travel a pre-defined service area.

5.4 GBLS Functional requirements synthesis

Figure 5-1 gives a synthetic view of the GBLS functional requirements identified above.

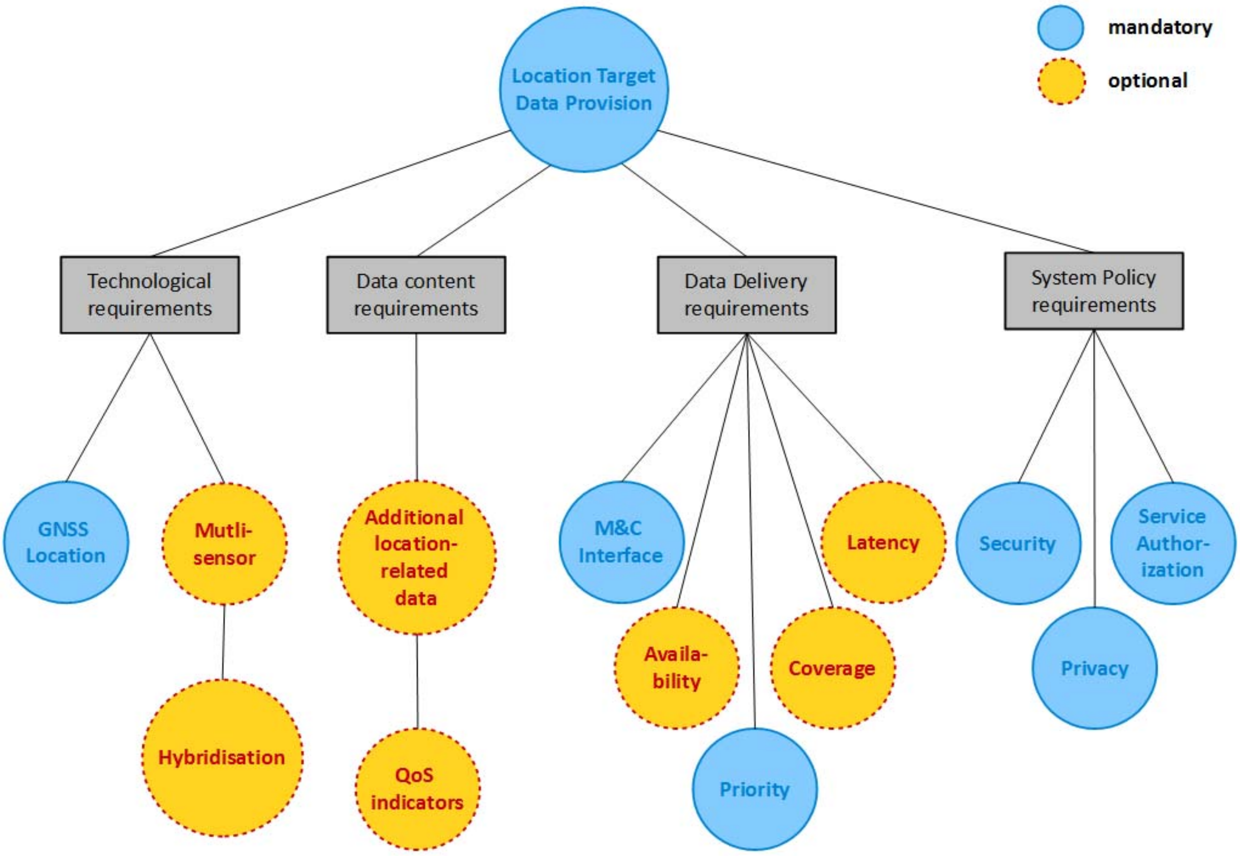

Figure 5-1: Functional requirements for GNSS-Based Location Systems

Annex A (informative): Common positioning techniques

A.1 GNSS methods

Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global or regional coverage. The following GNSSs are supported in the present document:

- GPS and its modernization (see [i.3], [i.4], and [i.5]);
- Galileo™ (see [i.6]);
- GLONASS (see [i.7]);
- Satellite Based Augmentation Systems (SBAS), including WAAS ([i.8]), EGNOS ([i.9]), MSAS, and GAGAN;
- Quasi-Zenith Satellite System (QZSS) (see [i.10]);
- BeiDou Navigation System (see [i.11]).

Each global GNSS can be used individually or in combination with others. When used in combination, the effective number of navigation satellite signals would be increased:

- extra satellites can improve availability (of satellites at a particular location) and results in an improved ability to work in areas where satellite signals can be obscured, such as in urban canyons;
- extra satellites and signals can improve reliability, i.e. with extra measurements the data redundancy is increased, which helps identify any measurement outlier problems;
- extra satellites and signals can improve accuracy due to improved measurement geometry and improved ranging signals from modernized satellites.

A.2 Assisted-GNSS methods

When a GNSS sensor is used as a part of a wider location system, other elements of this system can assist the GNSS sensor to improve the performance in several respects. These performance improvements will:

- reduce the GNSS start-up and acquisition times; the search window can be limited and the measurements speed up significantly;
- increase the GNSS sensitivity; when GNSS sensor operates in unfavourable SNR condition, provision of assistance messages internally to the location system can compensate the improper GNSS satellite signals demodulation;
- allow the GNSS sensor to consume less power from the positioning module than with stand-alone GNSS; this is due to rapid start-up times as the GNSS receiver can be in idle mode when it is not needed.

The assisted GNSS methods rely on communication between GNSS receiver embedded in the positioning module, and a so-called assistance server, part of the location system. This server mainly relies on a continuously operating GNSS reference receiver network, which has clear sky visibility of the same GNSS constellation as the assisted receiver. Two assisted modes are supported:

- *Terminal-Assisted*: The positioning module performs GNSS measurements (pseudo-ranges, pseudo Doppler, etc.) and sends these measurements to a central facility (part of the location system), where the position calculation takes place, possibly using additional measurements from other (non GNSS) sources.
- *Terminal-Based*: The positioning module performs GNSS measurements and calculates its own location, possibly using additional measurements from other (non GNSS) sources.

The assistance data content may vary depending on whether the positioning module operates in Terminal-Assisted or Terminal-Based mode.

The assistance data signalled to the terminal can be broadly classified into:

- *data assisting the measurements*: e.g. reference time, visible satellite list, satellite signal Doppler, code phase, Doppler and code phase search windows;
- *data providing means for position calculation*: e.g. reference time, reference position, satellite ephemeris, clock corrections.

A positioning module with GNSS measurement capability may also operate in an autonomous (standalone) mode without assistance from the network.

Table A-1 indicates where the various (A-)GNSS techniques processing take place function of the supported mode.

Table A-1: Location Service Requests

Processing step	A-GNSS Terminal-Assisted	A-GNSS Terminal-Based	GNSS Standalone
Baseband processing	Terminal	Terminal	Terminal
Pseudorange calculation	Terminal	Terminal	Terminal
Position calculation	Central Facility	Terminal	Terminal
Decoding of Satellite data	Central Facility	Central Facility	Terminal
Selection of Satellites	Central Facility	Central Facility	Terminal

A.3 Proximity sensing

The determination of the position of a mobile target can be executed by identifying that it is in the vicinity of a reference point whose position is well known.

The case of cellular telecommunication networks offers a privileged opportunity to execute such method. Indeed, a cellular network is a wireless network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a base station. These base stations are reference points. Identifying the transceiver to which a terminal is connected allows to locate it inside the associated cell.

Furthermore, this technique is applicable in the case of WiFi networks or Bluetooth device.

Regardless of which technique is used the term "base station" is used to identify the source of the signal on which the proximity sensing is executed, and whose position provides the location estimate. Identically, the "cell" is the area covered a base station.

This technique requires that the position of the base station is somehow known from by the positioning module.

It represents the easiest way to determine the position of a compatible positioning module, but suffers from poor accuracy. Indeed, accuracy of the obtained location depends on the size of the cells, hence of the density of base station.

Typical example of such technique is Cell-ID (CID) for UMTS and LTE cellular networks.

A.4 Multilateration

Enhancements of the previous method are possible if *range* or *range difference* measurements between the mobile target and the several base stations are achievable.

Several such techniques exists :

- Circular multilateration; range measurements are executed with at least 3 separate base stations; Each range measurement locates the terminal on a sphere or circle centered on the base station (including uncertainty due to measurement); the intersection of the spheres or circles provides a positon estimate.
  Ranging measurements can be obtained using various techniques with various accuracy: measurement of the received signal strength or of the propagation time.

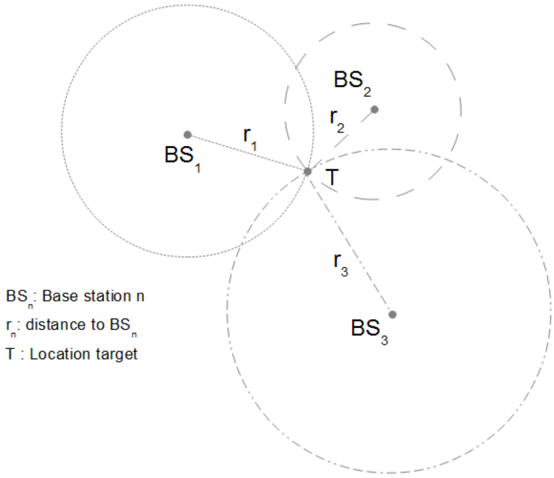

Figure A-1: Circular multilateration method

- Hyperbolic multilateration; this method rather relies on measurement of the range difference between the terminal and surrounding base stations; each range difference measurement, executed for a pair of base station, locates the terminal on a hyperbola with its focal points on the 2 base stations; the intersection of the hyperbolas provides a position estimate.

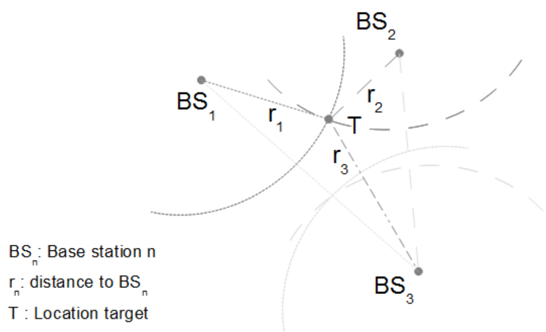

Figure A-2: Hyperbolic multilateration method

Note that since multilateration requires measurements executed on several base stations, the position of the neighbouring transceivers needs to be known.

Typical example of circular multilateration is the enhanced cell-ID method (E-CID) used for LTE networks.

Note that GNSS technique is a circular lateration technique, using a dedicated system whose primary purpose is positioning. Downlink multilateration techniques mentioned above are techniques built upon existing cellular networks whose primary objective is telecommunication. These techniques therefore mainly rely on the use of existing mechanisms, signals and measurements to determine the terminal position.

Typical examples of hyperbolic multilateration are Enhanced Observed Time Different (E-OTD) used for GSM network, Observed Time Difference of Arrival (OTDOA) for UMTS and LTE networks. For both techniques, measurements are obtained at cellular network terminal level.

An additional hyperbolic multilateration method relies on uplink measurements. This is the case of Uplink Time Difference of Arrival (U-TDOA) method used for GSM networks. Such methods are network-based, so that no measurement is available at terminal level. Position only would be available at terminal level.

A.5 Triangulation

Multilateration brings more accuracy by using ranging measurements between the mobile target and reference points. Triangulation brings more accuracy by using angle of visibility of a mobile target from various observation points.

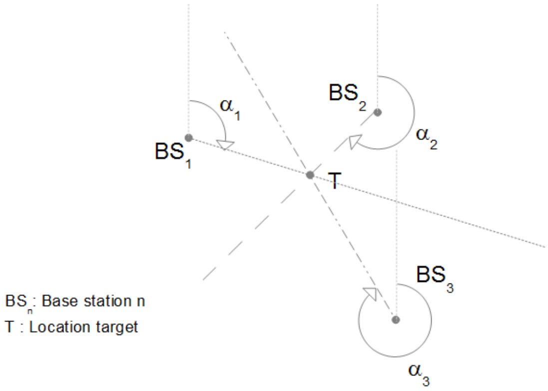

Figure A-3: Triangulation method

A.6 Multi-sensor positioning through (A-)GNSS hybridization

The hybridization of GNSS sensors with other navigation systems is the computation of a final data (position, speed, heading) from intermediate data provided by these systems. The idea behind this association is to develop a hybrid system more robust in operational conditions (interference and multipath, loss of GNSS signal), and more accurate.

The type of intermediate data to be processed depends on the hybridization methods used, and the type of navigation systems considered.

Several levels of hybridization exist:

- In the first level, each navigation source, including GNSS sensor, provides the information of position and velocity of the mobile target. A unique position is then computed from the various available position (average, weighted average, etc.)This is called "loose" coupling.

- An enhanced level of hybridization can be reached if ranging measurements are provided by the various navigation sources, thus providing estimates of distances between the mobile target and a number of reference points. The final position is then computed feeding these measurements in a single navigation algorithm. This is called "tight" coupling.

- Finally, if it is possible to have access to the heart of the GNSS sensor processing and more particularly to the tracking loops, "ultra-tight" level of integration can be implemented. In that case, information collected from the other navigation sources are used to improve the measurement quality and thus obtain enhanced navigation solution.

The navigation source listed below provide data injectable in an hybridization algorithm:

- Inertial Navigation Sensor (INS): data from accelerometers and gyrometers can be used to improve the positioning performance.

- Odometer and tachometer: these devices, typical used in the automotive domain, provide valuable information on the mobile target movement; in addition, when installed on the 2 front (or rear) wheels of a car they provide information on car gyration.

- Cellular network modem: such sensors can provide various location-related information, from estimate location (accuracy depending on the method), down to base station ranging measurements.

Annex B (informative): GBLS High level functional analysis

Tables B-1 and B-2 indicate the mapping between :

- the location based applications needs, either common or specific as defined in clause 4.1; and
- the GBLS functional requirements which were derived from these needs, either mandatory or optional as defined in clauses 5.1 and 5.2.

Table B-1: Common application needs mapping to mandatory GBLS requirements

		GBLS Functional requirements						
		Use of GNSS	M&C Interface	Priority	Security	Privacy	Service Authorization	Target identification
Application Needs	Multiple end users		x	x			x	
	Multiple location targets			x				x
	Privacy protection policy					x		
	Data protection policy				x			
	A priori unknown location-related data	x						
	Availability over Wide area	x						

Table B-2: Specific application needs mapping to optional GBLS requirements

		GBLS Functional requirements						
		Multi-sensor	Hybridization	Additional loc data	QoS indicator	Availability	Coverage	Latency
Application Needs	Reliability of check point crossing detection	x	x		x			
	Service availability					x	x	x
	Representativity of the travelled trajectory or distance	x	x	x				
	Accuracy of the reported position	x	x					
	Fraud Detection	x			x			
	Positioning Performance Monitoring	x			x			
	Accuracy of movement caption	x	x	x	x			

History

Document history		
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