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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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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 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [10].

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

The increasing expansion of location-based applications aims to satisfy more and more complex and diversified user requirements: this is highlighted for example by the widespread adoption of multi-functional smart-phones or by the ever wider adoption of tracking devices (e.g. in transport), etc. This requirement for new and innovative location-based applications is generating a requirement for increasingly complex location systems.

The wide spectrum of location-based applications identified in [i.1] calls for a new and broader concept for location systems, taking into account solutions in which GNSS technologies are complemented with other technologies to improve robustness and performance. The notion of **GNSS-based location systems** is introduced and defined in this standard.

Additional clauses and information related to the implementation in **GNSS-based location systems** of the various differential GNSS technologies, namely D-GNSS, RTK and PPP are also included in order to facilitate the use of this set of standards by manufacturers and service providers.

Hence a set of standards for GNSS-based Location systems is defined of which the present document is part 2.

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1 Scope

This multi-part deliverable addresses integrated GNSS based location systems (GBLS) 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. As a consequence the present document is not applicable to GNSS only receivers.

This multi-part deliverable proposes a list of functional and performance requirements and related test procedures. For each performance requirement, different classes are defined allowing the benchmark of different GNSS Based Location Systems (GBLS) addressing the same applications.

The architecture specified herein is a "functional" architecture, meaning that the system is defined in terms of discrete functional elements connected to other internal or external functional elements via associated "logical" interfaces. These functional elements and interfaces are derived from service requirements.

The functional architecture is not necessarily related to the "physical architecture" (i.e. the relationship between equipment which may implement all or some of these functions, and the physical interfaces between them).

The present document can be considered as the Stage 2 functional specification according to the ITU/3GPP approach [i.4].

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.

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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] IS-GPS-200D: "Revision D, Navstar GPS Space Segment/Navigation User Interfaces", March 7th, 2006.

[2] IS-GPS-705D: "Navstar GPS Space Segment/User Segment L5 Interfaces", September 24, 2013.

[3] IS-GPS-800D: "Navstar GPS Space Segment/User Segment L1C Interfaces", September 24, 2013.

[4] "Galileo OS Signal In Space ICD (OS SIS ICD)", Issue 1.2, EU/GSA.

[5] BDS-SIS-ICD-B1I-2.0 (December 2013): "BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal (Version 2.0)".

[6] "Global Navigation Satellite System GLONASS Interface Control Document", Version 5.1, 2008.

[7] IS-QZSS: "Quasi Zenith Satellite System Navigation Service Interface Specifications for QZSS", Version 1.0, July 31st, 2009.

[8] IRNSS SIS ICD For Standard Positioning Service, ISRO-IRNSS-ICD-SPS-1.0.

[9] RTCM 10403.2: "Differential GNSS (Global Navigation Satellite Systems) Services".

[10] ETSI TS 103 246-1: "Satellite Earth Stations and Systems (SES); GNSS based location systems; Part 1: Functional requirements".

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

[12] RTCM 10401.2: "Standard for Differential Navstar GPS Reference Stations and Integrity Monitors (RSIM)".

[13] US Department of Transportation, Federal Aviation Administration: "Global Positioning System Wide Area Augmentation System (WAAS) performance Standard" - 1st Edition - 31 October 2008.

NOTE: Available at http://www.gps.gov/technical/ps/2008-WAAS-performance-standard.pdf.

[14] RTCA DO-229D: "Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment".

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

[i.2] ETSI TS 103 246-4: "Satellite Earth Stations and Systems (SES); GNSS based location systems Part 4: Requirements for location data exchange protocols".

[i.3] ETSI TS 103 246-5: "Satellite Earth Stations and Systems (SES); GNSS based location systems Part 5: Performance Test specification".

[i.4] Void.

[i.5] M. A. Abdel-Salam: "Precise Point Positioning Using Un-Differenced Code and Carrier Phase Observations", PH.D. Thesis, Department of Geomatics Engineering, Calgary, Alberta (CAN), September 2005.

[i.6] ETSI TS 103 246-3: "Satellite Earth Stations and Systems (SES); GNSS based location systems Part 3: Performance requirements".

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3 Definitions and abbreviations

3.1 Definitions

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

Accumulated Delta Range (ADR): Another term for carrier phase measurement.

application module: entity in charge of retrieving from a location system the location-related data associated with 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 the terminal.

authentication: provision of assurance that the location-related data associated with a location target has been derived from real and not falsified signals

architecture: abstract representation of a communication 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 peer relationships.

availability: percentage of time that a location system is able to provide the required location-related data

carrier phase measurement: measure of the range between the satellite and receiver expressed in units of cycles of the carrier frequency

continuity: likelihood that the location system functionality will be available during the complete duration of the intended operation if the system is operational at the beginning of the operation

D-GNSS: technique aiming at enhancing position accuracy and integrity of a GNSS receiver by using differential pseudorange corrections and "do not use flag" for faulty satellites delivered by a GNSS reference station located at a known location

NOTE: In the present document, the term D-GNSS refer to conventional differential GNSS.

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

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

GNSS-based location system (GBLS): location system using GNSS as the primary source of positioning

GNSS only receiver: location receiver using GNSS as the unique source of positioning

integrity: measure of the trust in the accuracy of the location-related data provided by the location system and the ability to provide timely and valid warnings to users when the location system does not fulfil the condition for intended operation

NOTE: Integrity is expressed through the computation of a protection level. The Integrity function is built to deliver a warning (or alert) of any 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 (i.e. a positioning error higher that the protection level) without annunciation for a time longer than the time-to-alert limit.

Integrity Monitor (IM): only applicable to conventional D-GNSS. A component of the D-GNSS Reference Station which is responsible for validating the integrity of the correction computation and broadcast signals

NOTE: When this IM component detects anomalies, it reports these conditions to the Reference Station component.

jamming: deliberate transmission of interference to disrupt reception of desired signals, which in this case are GNSS or telecommunication signals

NOTE: Spoofing is considered to be a deceptive form of jamming.

latency: measure of the time elapsed between the event triggering the determination of the location-related data for a location target and the availability of the location-related data at the user interface

location-based application: application which is able to deliver a service to one or several users, built on the processing of the location information (location-related data) related to one or several targets

location-related data: set of data associated with a given location target, containing one or more 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)

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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 gathers the location information and manages the communication of the location-related data to the application module, which is the location system external client

location target: physical entity (mobile or stationary) whose position is the focus of the location related data to be built by the location system

privacy: function of a location system designed to ensure that the location target user's private information (identity, bank accounts, etc.) and its location-related data cannot be accessed by an unauthorized third party

positioning module: logical entity inside a location target responsible for providing, as a minimum, the relevant measurements for locating the target

NOTE 1: In some cases, the positioning module will also determine the location of the target and provide the location related data to the application module. In other cases, it will provide raw measurements to the location system central facility (enabling it to determine the location target location-related data). In all case, it includes the group of sensors required to execute these tasks. This group can include navigation sensors (GNSS, terrestrial beacons, Inertial, Odometers, etc.)

Precise Point Positioning (PPP): differential GNSS technique that uses a worldwide distributed network of reference stations to provide, in quasi real time, a highly accurate geodetic positioning of a receiver

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: distance between a satellite and a GNSS receiver as estimated by the receiver without correction for the receiver's time error

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

Pseudo Range Correction (PRC): simple difference between a pseudorange measured by a GNSS reference station, set at a known location and the estimated range between the satellite and this known location

NOTE 1: The estimated range generally uses the computed satellite clock bias correction and may use the estimated receiver clock bias correction.

NOTE 2: The Pseudo Range Correction represents an estimate of the total GNSS systematic error observed on one satellite line-of-sight, comprising ionospheric delay, tropospheric delay and orbito-synchro residual error. It can be directly used in a local area around the reference station to cancel most of the systematic errors.

quality of service: 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 include an accuracy estimate, a protection level statistic, the integrity risk, an authentication flag.

Real Time Kinematic (RTK): particular Differential GNSS technique that provides, in real time, highly accurate positioning of a target based on carrier phase measurements

NOTE 1: In the RTK context, the target is called the "rover", as opposed to the stationary reference station(s). RTK makes use of the carrier phase measurements, both in the reference station and in the rover, and this technique allows the ambiguities affecting these accurate measurements to be resolved.

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NOTE 2: If the reference station is at an accurately known location, the rover can compute its accurate geodetic (or absolute) location. Alternatively, if the reference station's geodetic location is only roughly known, RTK can still provide high accuracy, but only on a relative and not absolute basis.

reference receiver: receiver placed at a known and surveyed position used for differential GNSS technique

NOTE: A reference receiver is an essential component of a reference station.

reference station: station placed at a known and surveyed position aiming at determining and sharing the systematic errors of at least one GNSS constellation

NOTE: It can be isolated, and in this case will be integrated in the GBLS, or can be part of a network which itself can be a part of the GBLS or can be part of the network of an external differential GNSS service provider.

security: function of a location system designed to ensure 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

terminal-assisted: mode in which the terminal performs only the GNSS measurements (pseudoranges, pseudo Doppler, etc.) and sends these measurements to a remote central facility where the position calculation takes place

NOTE: This calculation may possibly use additional measurements or data from other sources (GNSS server assistance, differential GNSS services or non GNSS sensors etc.).

terminal-based: mode in which the terminal performs the GNSS measurements and calculates its own location

NOTE: This calculation may possibly use additional measurements or data from other sources (GNSS server assistance, differential GNSS services or non GNSS sensors etc.)

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

Time-To-First-Fix (TTFF): time taken by the receiver to produce the first position and time fix whose accuracy is lower than a defined accuracy limit, starting from the moment the receiver is switched on

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3.2 Abbreviations

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

3GPP	3rd Generation Partnership Project
ADR	Accumulated Delta Range
A-GNSS	Assisted GNSS
AOA	Angle Of Arrival
CF	Central Facility
CID	Call IDentifier
CMM	Central Management Module
CPCM	Centralized Position Calculation Module
DGNSS	Differential GNSS
D-GNSS	Differential GNSS
EGNOS	European Geostationary Navigation Overlay System
EMA	EMI Mitigation Algorithm
EMI	Electro-Magnetic Interference
FKP	Flächen Korrektur Parameter (German)
GAGAN	GPS Aided Geo Augmented Navigation System
GBAS	Ground Based Augmentation Systems
GBLS	GNSS-based Location System
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
IBA	Integrity Building Algorithm
IM	Integrity Monitor

IMU	Inertial Measurement Unit
INS	Inertial Navigation Sensor
IRNSS	Indian Regional Navigation Satellite System
ITS	Intelligent Transport Systems
LAAS	Local Area Augmentation System
LBS	Location-based Services
LHA	Location Hybridization Algorithm
LTE	Long Term Evolution
M&C	Monitoring and Control
MAC	Master Auxiliary Corrections
MD	Map Database
MSAS	Multi-functional Satellite Augmentation System
NRTK	Network RTK
OBPCM	On-board Position Calculation Module
OTD	Observed Time Difference
OTDOA	Observed Time Difference Of Arrival
PL	Protection Level
PM	Positioning Module
PPP	Precise Point Positioning
PVT	Position, Velocity and Time
QoS	Quality of Service
QZSS	Quasi-Zenith Satellite System
RF	Radio Frequency
RSIM	Reference Station Integrity Monitor
RSS	Received Signal Strength
RTCM	Radio Technical Commission for Maritime Services
RTK	Real Time Kinematic
SBAS	Satellite Based Augmentation System
SDCM	System for Differential Corrections and Monitoring
SNR	Signal-to-Noise Ratio
SSR	Space State Representation
TDOA	Time difference Of Arrival
TOA	Time Of Arrival
UHF	Ultra High Frequency
VHF	Very High Frequency
VRS	Virtual Reference Station
WAAS	Wide Area Augmentation System
WARTK	Wide Area RTK
Wi-Fi	Wireless Fidelity

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4 Requirements for GNSS-based Location Systems

The Reference Architecture for GNSS-based Location Systems (GBLS), as defined in the following clauses, is derived from the GBLS Functional Requirements [10] which are intended to provide one or more users with location-related data (as defined in ETSI TS 103 246-1 [10]) associated with one or more Location Targets. An overview of these requirements is given below.

The GBLS is intended to be a "generic" location system, and thus to encompass a wide range of functions associated with GNSS Location-based Services (LBS). The functions defined as "mandatory" form the basis of the GBLS, whilst the optional functions are also included in the architecture to provide additional choices to allow different architectural implementations, and additional location-related data to be provided (e.g. GBLS implementing assisted or differential GNSS techniques).

A particular GNSS-based application may require only a subset of the range of data available in the GBLS architecture. Therefore a subset of the GBLS architecture, with alternative combinations of subsystems, may only be required for many applications. For example, the location data provided can range from simple position-reporting in the case of low-end asset management, to reliable information (e.g. authenticated and with a known uncertainty) and/or high accurate information on the target's trajectory for liability-critical services such as road charging or Intelligent Transport Systems (ITS). Some examples of location system implementations (or Implementation Profiles) are given in ETSI TS 103 246-5 [i.3] where different combinations of architecture elements are subject to testing.

The functional requirements of the GBLS for location-related data provision are illustrated in Figure 4-1.

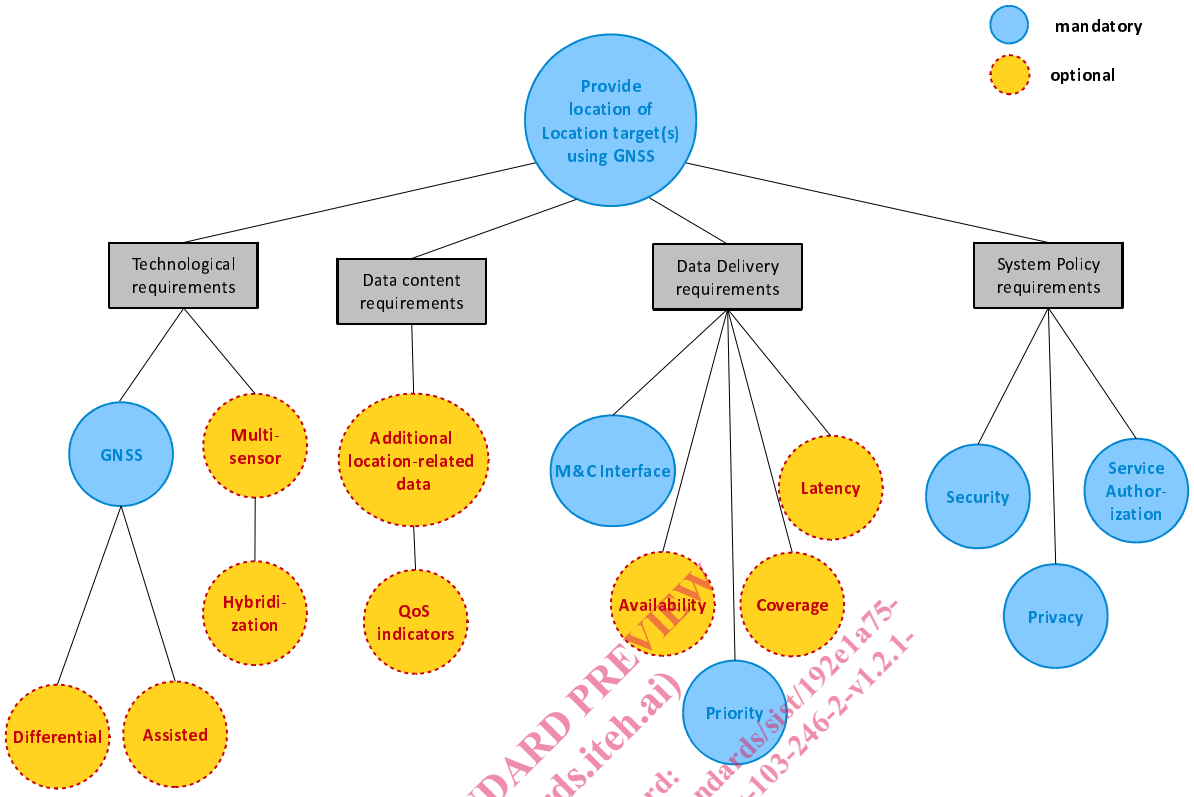

Figure 4-1: GBLS Functional Requirements

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Figure 4-1 shows the mandatory and optional functional requirements for the GBLS, grouped into four general requirement areas. The requirements were derived from a functional analysis of typical GBLS use cases, and are summarized below:

- Technological requirements: GNSS and, optionally, multi-sensor techniques together with measurement fusion methods are required to satisfy the range of potential applications. GNSS includes stand-alone positioning, as well as optional techniques that can improve the performance, for example assisted GNSS and differential GNSS (WADGNSS, D-GNSS, RTK, NRTK, PPP).

- Data content requirements: the GBLS is required to provide at least location target(s) position(s), and optionally, additional location-related data (such as speed, acceleration, heading, angular speed and angular acceleration) and quality of service indicators (such as data accuracy, integrity and authenticity).

- Data delivery requirements: the GBLS is required to implement an external interface conveying location-related data, and allow monitoring and control of data provisioning (including request priority management). Optionally, in order to comply with service level requirements when applicable, GBLS could meet pre-defined availability, coverage and/or latency performance requirements.

- System policy requirements: due to the sensitive nature of the data handled by the GBLS it is required to implement appropriate privacy protection policy (for the user), authorization policy (to identify authorized requesting entities) and security policy (protection of sensitive information against disclosure or alteration).

5 GBLS Architecture (Level 1)

5.1 Level 1 architecture functional blocks and logical interfaces

The functional requirements summarized in clause 4 are used in this clause to define mandatory and optional functional elements to be included in the GBLS Architecture. These elements are grouped into higher level functional blocks with common features.