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GNSS based location systems;
Part 2: Reference Architecture

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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 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 information 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 2.

1 Scope

The present document addresses generic architectures for GNSS-based Location Systems (GBLSs) that combine Global Navigation Satellite Systems (GNSS - e.g. Galileo™) and other navigation technologies with telecommunication networks for delivery of location-based services.

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 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.

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

[2] IS-GPS-705: "Navstar GPS Space Segment/User Segment L5 Interfaces", September 22, 2005.

[3] IS-GPS-800: "Navstar GPS Space Segment/User Segment L1C Interfaces", September 4, 2008.

[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, 2002.

[7] IS-QZSS, Quasi Zenith Satellite System Navigation Service Interface Specifications for QZSS, Ver.1.0, June 17, 2008.

[8] DTFA01-96-C-00025 (2001): "Specification for the Wide Area Augmentation System (WAAS)", US Department of Transportation, Federal Aviation Administration.

[9] RTCM-SC104 (V3.2): "RTCM Recommended Standards for Differential GNSS Service", February 2013.

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

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.

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

[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.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

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: Authentication is one of the key performance features that may be required of a location system.

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

NOTE 1: The required location-related data might vary between location based applications.

NOTE 2: It may contain more than a required information type (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 of 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 an interfering radio signal is deliberately broadcast to disrupt the communication.

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 an alert limit being exceeded) to users within a given period of time (*time-to-alert*). Conversely, 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 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 in a location system of the time elapsed between the event triggering the determination of the *location-related data* for one or more *location targets* (i.e. a location request from an external client, an external or internal event triggering location reporting), and the availability of the *location-related data* at the user interface

location-based application: application for delivering a *location-based service* to one or more users

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

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

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

NOTE: This entity may be mobile or stationary.

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

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.

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

Quality of Service (QoS): 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*, and authentication flag.

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

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

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

Time-To-First-Fix: 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, co-linear 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
A-GNSS	Assisted GNSS
AOA	Angle Of Arrival
CF	Central Facility
CID	Call IDentifier
CLM	Centralized Location Module
CMM	Central Management Module
DGNSS	Differential GNSS
D-GNSS	Differential GNSS
DGPS	Differential Global Positioning System
EGNOS	European Geostationary Navigation Overlay System
EMA	EMI Mitigation Algorithm
EMI	Electro-Magnetic Interference
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
IMU	Inertial Measurement Unit
INS	Inertial Navigation Sensor
ITS	Intelligent Transport Systems
LAAS	Local Area Augmentation System
LBS	Location-based Services
LHA	Location Hybridization Algorithm
LTE	Long Term Evolution
MD	Map Database
MSAS	Multi-functional Satellite Augmentation System
NDGPS	Nationwide Differential Global Positioning System (US)
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
RSS	Received Signal Strength
RTK	Real Time Kinematic
SBAS	Satellite Based Augmentation System
SNR	Signal-to-Noise Ratio
TDOA	Time difference Of Arrival
TOA	Time Of Arrival
WAAS	Wide Area Augmentation System
WARTK	Wide Area RTK
WIFI	Wireless Fidelity

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 [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 the additional choices to allow different architectural implementations to be included, and additional location-related data to be provided.

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 needed 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) 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 [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.

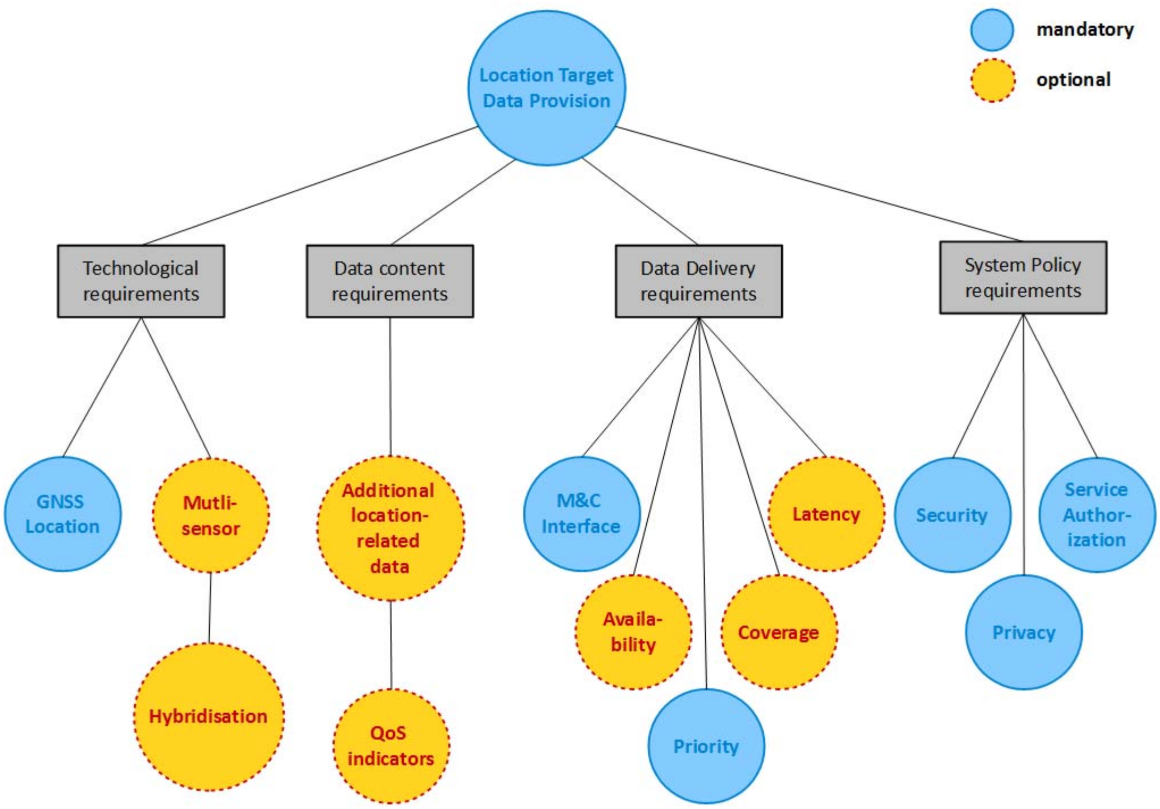

Figure 4-1: GBLS Functional Requirements

Figure 4-1 shows the mandatory and optional functional requirements for the GBLS, grouped into four general requirements 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.
- 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.
- 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), authorisation 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.

In the following clauses the GBLS Architecture is defined hierarchically, starting in this clause with the top-level (Leve 1) overall architecture. In subsequent clauses the architecture is decomposed into more detailed Level 2 and 3 architectures. These definitions in each case are of functional architectures; the Functional Elements (Blocks) needed for production of location-related data are defined, connected by logical interfaces which define information flows needed between the functional blocks (not necessarily with any relationship to physical interfaces), and also between the GBLS and any external elements.

Figure 5-1 depicts the highest level GBLS architecture.

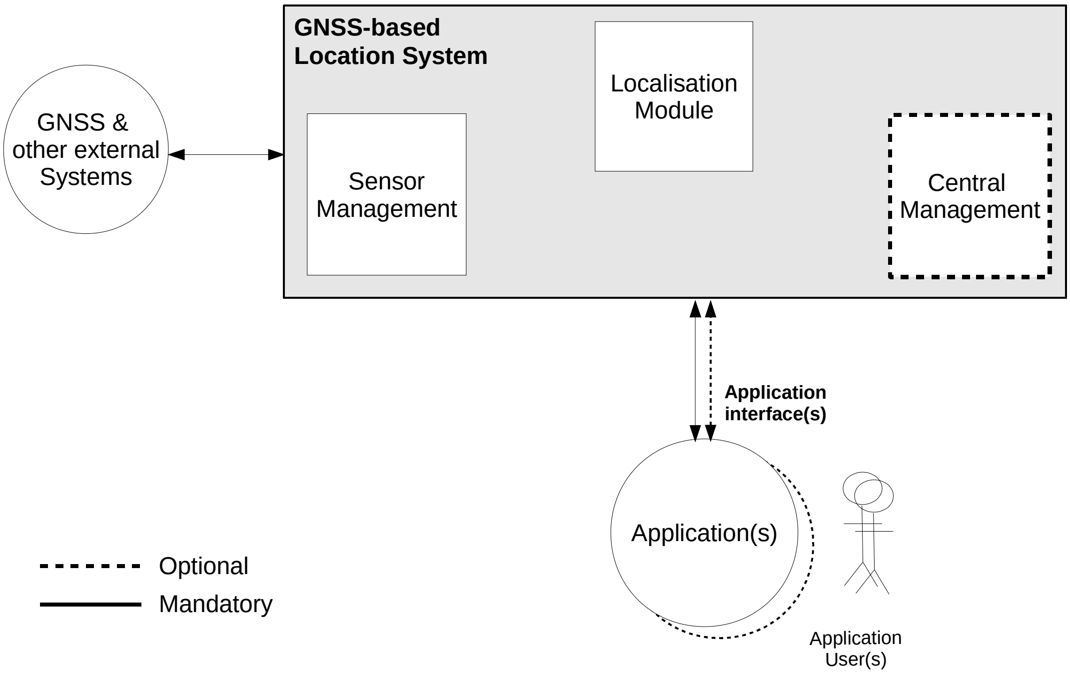

Figure 5-1: GNSS-based Location System (GBLS) Architecture (Level 1)

The functional requirements defined in clause 4 are allocated to the GBLS functional blocks of Figure 5-1 as shown in Table 5-1.

Table 5-1: GBLS Functional Requirements allocation to GBLS Functional Blocks

Functional Reqt.	GBLS Functional Block			
	Sensor Management	Localisation Module	Central Management	Application Interface Module
GNSS	X	X		
Multi-sensor	X			
Hybridisation		X		
Additional loc data	X	X	X	
QoS indicator	X	X	X	
M&C Interface				X
Availability	X	X	(optionally)	X
Priority				X
Coverage	X			-
Latency	X			X
Security			-	X
Privacy			(optionally)	X
Service Authorisation			(optionally)	X

: mandatory (blue)
: optional (yellow)

In the following clauses, the elements of Figure 5-1 are described as follows:

- External functional blocks
- GBLS functions
- GBLS external interfaces.

NOTE: The Location Target is a physical object (including a person, vehicle, interference source, etc.) associated with the GBLS or with external functional blocks with which sensors or applications interact to provide its location-related data, but the Location Target is not otherwise specifically defined.

5.2 External Functional Blocks

5.2.1 GNSS and Other External Systems

5.2.1.1 GNSS

The elements defined in the following clauses are external to the GBLS, and have interfaces with it.

GNSS provide autonomous geo-spatial positioning with global or regional coverage. The following GNSS systems are supported in the present document:

- GPS and Modernized GPS [1], [2] and [3]
- Galileo [4]
- BeiDou [5]
- GLONASS [6]
- Satellite Based Augmentation Systems (SBAS), including WAAS, EGNOS, MSAS, and GAGAN [8]
- Quasi-Zenith Satellite System (QZSS) [7]
- Ground Based Augmentation Systems (GBAS) [9], including NDGPS and European DGPS

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

5.2.1.2 Other External Systems

Other external systems may include:

- Terrestrial telecommunications networks providing position information (e.g. 3G, 4G, wifi, etc.);
- Inertial Sensor;
- Magnetometer;
- Odometer/tachometer;
- Beam Forming Antenna.

5.2.3 Application(s)

One or more user applications in external systems or subsystems may interface to the GBLS. An application may obtain location-related data to build value-added services (such as fleet tracking, collision avoidance systems, and asset tracking), with which the user(s) may interact.

An application makes a request to the GBLS for location-related data of one or more location targets, to which the GBLS should reply if security and privacy requirements are met.

The specification of the application internal logic and its relationship to any external end-user is outside the scope of the present document.

5.3 GBLS Functions

The overall functions provided by the GBLS are:

- Sensor Management to collect measurement data from the sensors and to provide assistance data.
- Localization that derives and issues the positioning and other parameters of a location target(s) from sensor measurements.
- Central Management providing additional support functions

5.4 GBLS External Interfaces

The primary inputs to the GBLS are measurements form GNSS and other sensors.

The GBLS shall communicate with external applications to accept requests and subsequently provide requested location-related data.

For details of these interfaces see clause 7.2.

6 GBLS Architecture (Level 2)

6.1 Level 2 architecture mandatory and optional components

Figure 6-1 shows the Level 2 architecture which is derived from Figure 5-1, and where mandatory elements that shall be used for any implementation profile are indicated, together with optional components.

In this architecture a mandatory Positioning Module (PM) and an optional Central Facility (CF) are defined, reflecting the case where a compact low-power remote PM is needed together with a centrally located, more functional, CF. Only a self-contained PM may be needed in the simplest of systems.

The Localization Module from Figure 4-1 has been separated into two optional parts depending on the needs of the system.

The mandatory components are in the PM, namely:

- Sensor Management
- On-Board Localization Module
- Application Interface Module

It is possible that a service request and the data exchange are handled entirely within a PM. It is also common that the service request will be handled by both the PM and the CF in a shared manner.

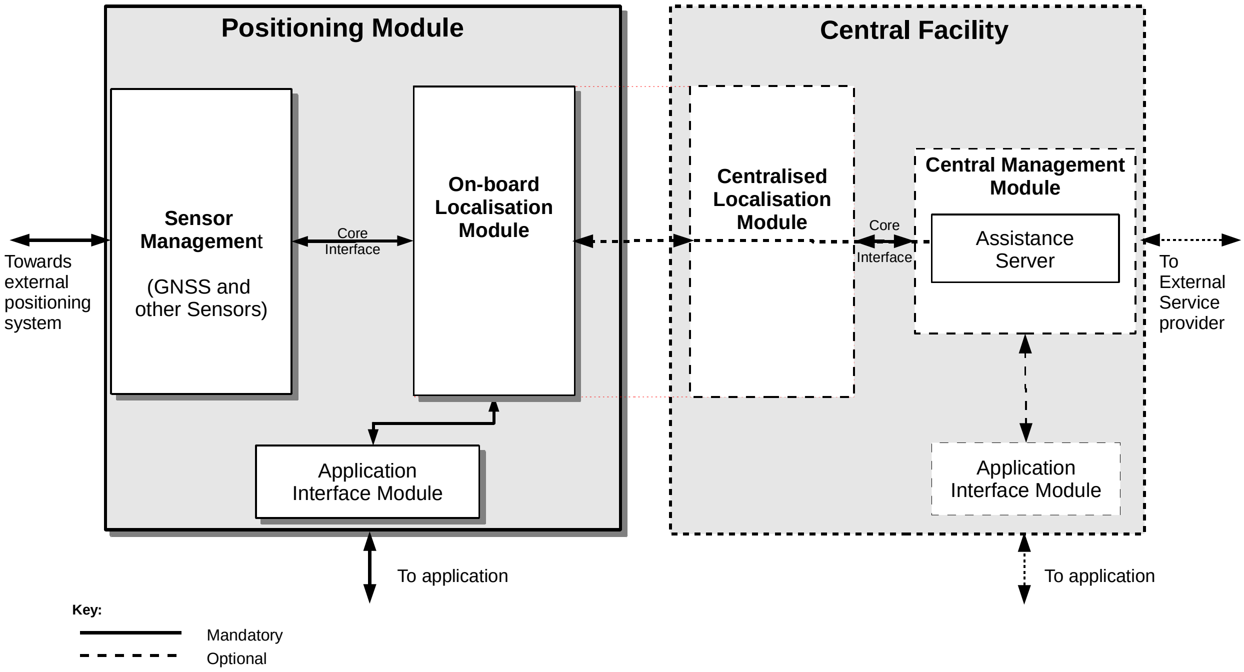

Figure 6-1: GBLS Architecture (Level 2)

NOTE: In the case where no Centralized Localization Module is present in the CF, the interface from the On-Board Localization Module passes directly to the Central Management Module (e.g. to the Assistance Server).

The Functional Elements (Blocks) of the PM and the CF are defined below, followed by the logical interface between them.

6.2 Positioning Module (PM)

6.2.1 Sensor Management

The sensor data management function provides the interface between each sensor and the On-Board Localization Module including:

- sensor-to-sensor feedback (e.g. INS-aided GNSS tracking);
- central management-provided assistance data to the sensors;
- the data encoding of sensor measurements to the Localization Module and vice-versa.

6.2.2 On-board Localization Module

The Localization Module consists of algorithms to process the data received from the sensors and produce location-related data.

These algorithms can be shared with the Centralized Localization Module in different ways:

- Allocated only to the On-Board module (e.g. for simple or self-contained systems).
- Allocated only to the CF.
- Shared between both on-board and centralized functions (e.g. when an implementation needs to embed a specific part of the algorithm on-board for ultra-tight hybridization, and to allocate the remaining processing at the central facility level to reduce remote power consumption).

6.2.3 Application Interface Module

The Application Interface Module shall support the following functions:

- request handling function: this function includes forwarding the required location-related data within the conditions specified by the request. It also manages the priority among the various requests received from one or several applications;
- [optional] profile management function: the purpose of this function is to manage all information related to the positioning modules. This information is typically a database containing terminal ID(s), user(s), privacy profiles, etc.
- [optional] service authorisation function: the purpose of this function is to verify that the service provider is authorized to provide the requested service.

6.3 Central Facility (CF)

6.3.1 Centralized Localization Module (CLM)

This Localization Module consists of algorithms that can be shared as defined in clause 6.1.2.

6.3.2 Central Management Module (CMM)

The Central Management Module shall provide one or more of the following services:

- Terminal assistance function: the purpose of this function is to enable assistance data that the Localization Module might require in order to perform its localization functions.
- Profile management functions: the purpose of this function is to manage all information related to location targets that are required to provide the GBLS service. This information is typically a database containing terminal ID(s), terminal user(s) privacy profile, etc.

This functional block optionally includes the Assistance Server, in charge of generating and providing assistance data to the positioning module.

6.3.3 Application Interface Module

The Application Interface Module is functionally identical to that defined for the PM (see clause 6.1.3).

6.4 Core Interface

The core interface represents all location data exchanges between:

- the sensors and the Localization Module;
- the Localization Module and the Application;
- the On-board Localization module and the Centralized Localization module.

The sensor interface to the localization module carries measurement data from the sensors such as the GNSS and inertial units, among others. The core interface also provides feedback to the sensors like assistance data that may be developed from the processing of sensor data or provided via the interface to the assistance server. The core interface between the sensors and the Localization module allows for tight integration of inertial and GNSS measurement processing. For example, the core interface provides a path for RF samples directly to the Localization Module for off-sensor processing of raw GNSS data.

For details of these interfaces see clause 7.2.

7 GBLS Architecture (Level 3)

7.1 Level 3 detailed architecture

Figure 7-1 shows the detailed (Level 3) architecture, which is derived from the Level 2 architecture in clause 6.1.

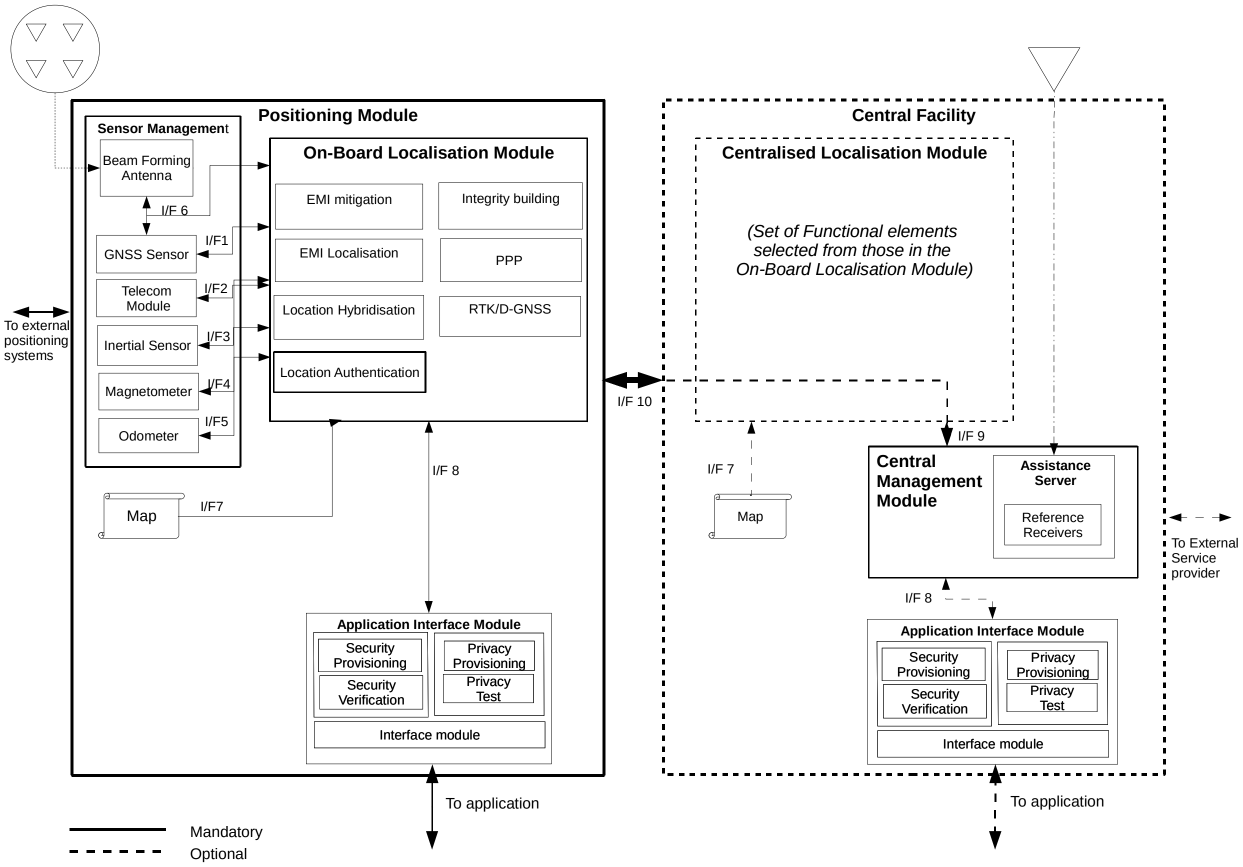

Figure 7-1: GBLS detailed architecture

7.2 Functional Block Definitions

7.2.1 List of functional blocks

The following clauses define the functions that shall be provided by each block of Figure 7-1, that is a detailed version of the diagram reported in Figure 6-1. The architecture in Figure 7-1 comprises the following functional blocks:

- GNSS sensor;
- Telecommunication module;
- Inertial Sensor;
- Magnetometer;
- Odometer/tachometer;
- Beam Forming Antenna;
- EMI mitigation algorithm;
- EMI localization algorithm;
- Location Hybridization Algorithm;

- Integrity building algorithm;
- PPP module;
- RTK/D-GNSS Module;
- Location Authentication;
- Security Provisioning;
- Security Verification;
- Privacy Provisioning;
- Privacy Test;
- Interface module;
- Reference Receivers;
- Assistance server;
- Map and data base.

7.2.2 GNSS Sensor

The GNSS sensor is a mandatory component of the GBLS architecture, and shall be on-board the positioning module of the location target. Refer to clause 6.1.1 for the functional block description.

7.2.3 Telecommunication Module

The Telecommunication Module is an optional component of the positioning module of the GBLS architecture. It determines the position of the location target by processing signals transmitted from terrestrial radio beacons (i.e. anchor nodes) at fixed and precisely known locations.

The Telecommunication Module might provide different types of measurements to the Localization Module:

- Angle of Arrival (AOA) measurements, sensing the angle of direction of the received signal.
- Received Signal Strength (RSS) measurements, estimating the received signal power.
- Time of Arrival (TOA) measurements, estimating the signal propagation delay.
- Cell Sector Location.

7.2.4 Inertial Sensor

The *Inertial Measurement Unit (IMU)* is an optional component of the positioning module of the GBLS architecture. IMU contains a set of as many as three orthogonally-installed accelerometers and/or as many as three orthogonally-installed gyroscopes to provide measurements of the acceleration and the angular rate on three-axes. Accelerometers and gyroscopes can be mounted on the IMU either in Gimballed or Strapdown configurations.

7.2.5 Magnetometer

The *Magnetometer* is an optional component of the positioning module of the GBLS architecture. It is used to measure the magnetic flux on as many as three axes that may be used to estimate the horizontal and vertical orientation of the location target.

7.2.6 Odometer

The Odometer is an optional component of the positioning module of the GBLS architecture. It is used to measure the distance travelled by the location target in a predefined time window.

7.2.7 Beam Forming Antenna

The Beam Forming Antenna is an optional component of the positioning module of the GBLS architecture.

The Beam Forming Antenna includes signal-processing techniques able to combine streams of samples from *n* different elements of an antenna array. The Beam Forming Antenna is used to steer the antenna beam pattern to the transmitting sources (i.e. GNSS satellites), therefore increasing the Signal-to-Noise Ratio (SNR).

The Beam Forming Antenna outputs a single stream of combined samples that can be processed by the GNSS sensor or by other components within Localization group of the Positioning module (e.g. EMI Mitigation).

7.2.8 EMI Mitigation

The EMI mitigation algorithm (EMA) is an optional component of the GBLS architecture.

This algorithm is in charge of detecting and mitigating RF interfering signals that can be present over bandwidths allocated to GNSS.

The EMI mitigation algorithm includes an interference detector that enables the mitigation functions. The EMI mitigation algorithm can process either before or after the correlators:

- Pre-correlation: takes sets of raw digital samples from the RF front end, before correlation.
- Post-correlation: takes sets of correlations available at the GNSS sensor, after correlation.

7.2.9 EMI Localization

The Electro Magnetic Interference (EMI) localization algorithm is an optional component of the GBLS architecture.

The presence of interfering sources (whether intentional or not) can degrade the GBLS performance. The EMI localization algorithm is responsible for determining the location-related data of RF interfering sources, transmitting over GNSS bands.

The EMI localization algorithm includes an interference detector and a direction indicator that are used to estimate the location of the interference source. The EMI localization algorithm can process signals either before or after correlation:

- Pre-correlation: sets of raw digital samples from the Radio Frequency (RF) front end, before correlation,
- Post-correlation: sets of correlations available at the GNSS sensor, after correlation.
- Enhanced EMI localization may be achieved by processing measurements from separated sensors that would require the centralized Localization module to perform the processing.

7.2.10 Location Hybridization Algorithm

The Location hybridization algorithm (LHA) is an optional component of the GBLS architecture.

The location hybridization algorithm is one of the algorithms responsible for determining the location-related data of a location target. It is specifically in charge of the processing needed in case the location targets are not interference sources. It is expected that location-related data may be computed using the fusion of measurements coming from GNSS sensors and possibly additional sensors (including maps), further it is expected that the Location Hybridization algorithm can rely on other system blocks to validate the integrity or authenticity of the measurement sources as required.

For example, the localization algorithm may integrate IMU measurements to enhance position, velocity and attitude.

7.2.11 Integrity Building Algorithm

The Integrity Building algorithm (IBA) is an optional component of the GBLS architecture.

The location hybridization algorithm is one of the algorithms in charge of executing the processing required to determine the location-related data of a location target. It is specifically in charge of the processing needed in case a reliable quality of service indicator is needed.

This algorithm shall be allocated according to one of the following rules:

- Allocated to positioning module (on-board function).
- Allocated to the CF.

The Integrity Building Algorithm shall include:

- An optional processing block and interface to GNSS sensor metrics (such as interference and multipath detection metrics) in case that such metrics produced by the GNSS receivers on top of the range measurements are compared to a threshold set according to the continuity and integrity risks and used to remove the corresponding range measurements before the computation of PVT and Protection Level.
- A processing block for the computation of the Protection Level based on the pseudo-range residuals scaled to the position domain.
- A processing block for the comparison of the resulting protection level with the application Alert Limit and the assessment of the integrity availability.

7.2.12 PPP Module

The *PPP Module* is an optional component of the GBLS architecture.

The PPP module provides precise estimates of the PVT, implementing algorithms able to mitigate most of the errors affecting GNSS positioning, due to:

- The space segment (i.e. receiver clock offset, satellite antenna phase centre offsets).
- The signal propagation (i.e. ionospheric delay model error, tropospheric delay model error, atmosphere loading).
- Other effects such as the Earth's rotation, the relative motion between satellites and the receiving GNSS antenna, gravitational forces and relativistic effects [i.5].

Position determination with the PPP module is based on the processing and combination of un-differenced code and phase observations. The PPP module receives as input, measurements from the standalone GNSS sensor and data (i.e. precise ephemerides) from a PPP service provider, external to the GBLS.

7.2.13 RTK/D-GNSS Module

The *RTK/D-GNSS* is an optional component of the GBLS architecture. This component includes algorithms in charge of:

- Applying differential corrections on sets of measurements (i.e. pseudo ranges) performed by the GNSS sensor. Differential corrections sent by different augmentation systems can be received through the Application Interface. The GNSS augmentation system include:
    - WAAS broadcasting differential corrections on bands allocated to GNSS.
    - Terrestrial data services, supporting ground-based access to WAAS differential corrections (e.g. EGNOS Data Access Service).
    - LAAS broadcasting differential corrections on a dedicated wireless channel.
    - GBAS broadcasting differential corrections on a dedicated wireless channel.
- Performing Real-Time-Kinematic (RTK) positioning. This requires the implementation of the RTK/D-GNSS block within the positioning module (on-board function, acting as rover) and within the central facilities (centralized function, acting as base, rover, or both). RTK algorithms implemented within the Localization module receive:
    - Carrier phase measurements performed by the on-board GNSS sensor (rover).
    - Position of the central facilities (base).

- Carrier phase measurements performed by the GNSS sensor installed at the central facilities (base).

RTK algorithms implemented within the positioning module estimate the baseline between rover and base that is used to determine location-related data of the location target.

RTK positioning can be also performed with GNSS sensors installed on two (or more) different Positioning Modules, one acting as rover, the other(s) as base.

7.2.14 Location Authentication

The Location Authentication is an optional component of the GBLS architecture.

This functional block includes algorithms in charge of authenticating the position computed by the location target. The authentication might be based on specific processing of the received GNSS signals and involves the detection, and possibly the mitigation, of structured RF interference (i.e. RF spoofing) over bands allocated to GNSS. If not detected, structured RF interference might deceive the GNSS sensor and cause the GBLS to provide a location not associated with the actual location target's position, but instead provide the location dictated by the spoofing signals without any notice.

Algorithms for location authentication include RF spoofing detectors that could enable subsequent mitigation functions. Algorithms for location authentication can process:

- Pre-correlation measurements, taking sets of raw digital samples from the RF front end (from the GNSS sensor and/or from the Beam Forming Antenna);
- Post-correlation measurements, taking sets of correlations available at the GNSS sensor;
- Pseudo-range and/or positions estimated by the GNSS sensor and set of measurements from other sensors (i.e. Inertial Sensor, Odometer, Magnetometer);
- Pseudo-range and/or positions estimated by the GNSS sensor and set of measurements from the Telco module.

The Location Authentication functional block may be implemented either within the PM and/or within the CF.

7.2.15 Security Provisioning

Security Provisioning is an optional block within the system architecture. Security provisioning is provided to allow devices to register their credentials to act as measurement or reference sources. The provisioning process allows for later security verification.

7.2.16 Security Verification

Security Verification is an optional block within the system architecture. Security verification is used to establish that the measurement source is a trusted, secure source.

7.2.17 Privacy Provisioning

Privacy provisioning is an optional block within the system architecture. Privacy provisioning is provided to allow a location target to register its privacy profile. This privacy profile will be consulted by the Application to direct the location process.

7.2.18 Privacy Test

The privacy test is an optional block within the system architecture. The privacy test consults the provisioning data of the location target to determine if the requesting entity should be granted access to the location of the target.

7.2.19 Application Interface Module

This is the interface that external applications use to exchange location requests and responses with the positioning system.

7.2.20 Reference Receivers

The Reference Receivers are optional components of the GBLS architecture. They are GNSS sensors in charge of processing GNSS signals at the Central Facility, in a fixed and precisely known location. Reference Receivers provide measurements post correlation (e.g. code and carrier phase measurements, Doppler, C/No estimates, Pseudo-ranges, Pseudo-range residuals, etc.) and PVT solutions. From a logical point of view, it is assumed that the Reference Receivers are connected to a geo-referenced GNSS antenna.

Reference receivers can be used to generate local area differential corrections (assuming the antenna is geo-referenced), monitor the quality of GNSS signals and compute integrity data.

7.2.21 Assistance server

The Assistance server is an optional component of the Central Facility of the GBLS architecture. As such, it shall implement at least one of the following functions:

- Provision of A-GNSS data (assistance data as defined in [i.2]).
- Provision of multi-lateration/Triangulation assistance data. This is applicable in case the GBLS has a high level of integration with cellular networks. In that case, it can provide information enabling techniques such as CID, E-CID, E-OTD, OTDOA, U-TDOA.
- Provision of precise positioning data, enabling DGNSS, RTK and WARTK data processing.
- Interface with external service providers. Such an interface might serve to recover ephemerides from external PPP service providers, to collect navigation or mission data from GNSS infrastructure, to receive cryptographic keys from GNSS infrastructure, to enable authentication service for encrypted GNSS signals, and others.

7.2.22 Map database

The M*ap database* (MD) is an optional component of GBLS architecture.

The Map database shall contain the digital map database with the graphical representation of all the spatial information needed for route guidance. It is based on:

- single-line-road-network representing the centreline of the road; and
- detailed description of the road attributes such as width, number of lanes, turn restrictions at junctions, and roadway classification (e.g. one-way or two-way road);
- statistical description of the map topological and geometric error;
- time reference to measure the database age.

The Map database shall optionally feed the following blocks in the Localization module:

- Location Hybridization Algorithm block in case that Map Matching algorithms are used to map-match position fixes onto the road map;
- Integrity Building Algorithm block.

This database shall be available on the positioning module, at the central facility, or on both.

7.3 Interfaces

The following location data exchanges are defined inside the GBLS architecture:

- I/F 1 GNSS Sensor to Localization Module

  GNSS sensors can provide a wealth of data in a variety of formats. This interface will allow RF samples, I/Q samples, Pseudo-range measurements, carrier phase measurements and carrier phase rate measurements. This interface also supports the GNSS navigation message data. Assistance data that may be formed by INS measurements or as provided by an assistance server are provided as feedback from the Localization module to the GNSS sensor over this interface.

- I/F 2 Telecommunication Module to Localization Module

  This interface allows for the exchange of ranging, angle of arrival or departure, signal strength and timing data from ground transmitters. The transmitter almanac data may also be present on this interface.

- I/F 3 Inertial Sensor to Localization Module

  When discussing sensor orientation we need to establish the reference frames. The following definitions are used to describe the references:

  - Case The orientation of the sensor suite in relation to the sensor housing (case).
  - Body Orientation of the Positioning Module ("Nose, Right Wing and Down").

  The inertial sensor interface shall allow for a three-axis turn rate measurement, along with a reference frame that defines the rotation required to align the case to body frame.

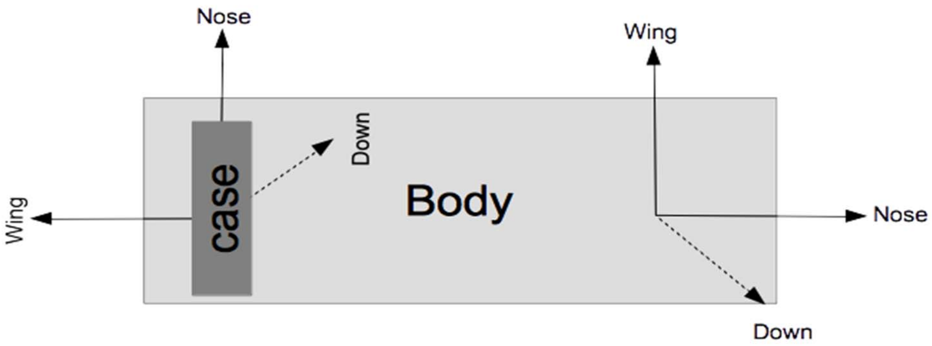

Figure 7-2

- I/F 4 Magnetometer to Localization Module

  The magnetometer interface shall allow for a three-axis measurement of the magnetic flux measured on each axis. The appropriate reference frames are required to allow sensor measurements to align with the Positioning module body.

- I/F 5 Odometer to Localization Module

  The odometer interface allows for time-tagged measurements of rotation rate and wheel radius or time-tagged step count and stride length to allow for the computation of speed and distance.

- I/F 6 Beam Forming Antenna to Localization Module or GNSS sensor

  The Beam Forming Antenna outputs a single stream of signal samples either to the GNSS sensor or to the blocks of the Localization Module (e.g. EMI Mitigation).

- I/F 7 Mapping Data to Localization Module

  The mapping data interface allows for the elements of the road network database to be provided to the localization module to perform map-aiding and integrity building. Location data flows to the mapping database as spatial search parameters.

- I/F 8 Central Management to Application Interface Module

  The CMM expects requests of position, velocity, and acceleration and performance requirements such as timing and accuracy requirements. The CMM responds with these parameters along with quality of service fields to provide confidence in the solution. These requests and responses may be relayed to the Localization Module. If there is no CMM in the CF, then this interface may be connected directly to the CLM.

- I/F 9 Assistance Server to Localization Module

  The Assistance server to localization module allows the exchange of request and responses of GNSS specific data elements, such as orbit models, time, code, phase and Pseudo-range.

- I/F 10 Localization Module to Localization Module

  All of the data elements that can be provided to a localization module from an assistance server or GNSS and other sensors shall also flow between localization modules. All intermediate computational elements are also allowed to flow between the localization modules. The on-board and central localization modules shall support identical interfaces to allow either module to derive any element of the localization process.

Annex A (informative): Bibliography

ETSI TR 101 593: "Satellite Earth Stations and Systems (SES); Global Navigation Satellite System (GNSS) based location systems; Minimum performance and features".

History

Document history		
V1.1.1	April 2015	Publication