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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 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".

Modal verbs terminology

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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 ETSI TR 103 183 [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 the present document.

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.

1 Scope

The present document defines the architecture applicable to location systems. This 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].

ETSI TS 103 246 part 1 [10], part 3 [i.6], part 4 [i.2] and part 5 [i.3] address 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.

ETSI TS 103 246 part 1 [10], part 3 [i.6], part 4 [i.2] and part 5 [i.3] propose 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.

2 References

2.1 Normative references

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

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

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

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

[1] IS-GPS-200K: "Navstar GPS Space Segment/Navigation User Segment Interfaces".

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

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

[4] "European GNSS (Galileo) Open Service Signal In Space Interface Control Document", Issue 1.3.

[5] BDS-SIS-ICD-B1I-3.0: "BeiDou Navigation Satellite System Signal In Space Interface Control Document; Open Service Signal B1I (Version 3.0)".

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

[7] IS-QZSS-PNT-003: "Quasi-Zenith Satellite System Interface Specification Satellite Positioning, Navigation and Timing Service", revision 003.

[8] ISRO-IRNSS-SIS-ICD-SPS-1.1: "Signal In Space ICD For Standard Positioning Service Version 1.1".

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

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

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

[15] BDS-SIS-ICD-B1C-1.0: "BeiDou Navigation Satellite System Signal In Space Interface Control Document; Open Service Signal B1C (Version 1.0)".

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] 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.

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

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

accuracy (or error): difference between a measured or estimated value and its real value

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.

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.

authentication: process/protocol to provide authenticity

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

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)

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: 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.

Pseudorange 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 orbital bias 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.

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

3.2 Symbols

Void.

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	Cell IDentifier
CMM	Central Management Module
CPCM	Centralized Position Calculation Module
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
D-GNSS	Differential GNSS
EDAS	EGNOS Data Access Service
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
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
GPRS General Packet Radio Service
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
KSM Key Storage and Management
LAAS Local Area Augmentation System
LAD-GNSS Local Area D-GNSS
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
NMA Navigation Message Authentication
NRTK Network RTK
NTRIP Networked Transport of RTCM via Internet Protocol
OBPCM On-Board Position Calculation Module
OSNMA Open Service Navigation Message Authentication
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
RTC Real Time Clock
RTCA Radio Technical Commission for Aeronautics
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
TS Technical Specification
TTFAF Time-To-First-Authenticated-Fix
UHF Ultra High Frequency
UMTS Universal Mobile Telecommunications System
VHF Very High Frequency
VRS Virtual Reference Station
WAAS Wide Area Augmentation System
WAD-GNSS Wide Area D-GNSS

WARTK	Wide Area RTK
Wi-Fi®	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 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.

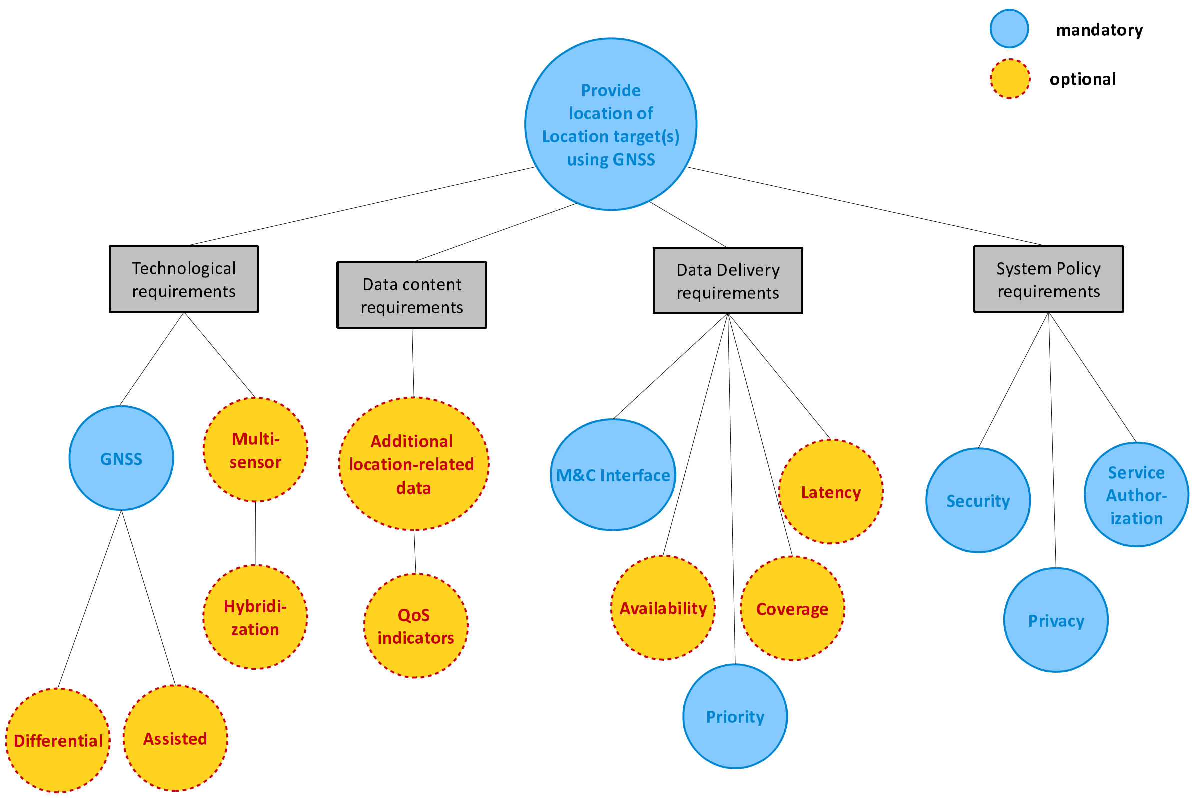


Figure 4-1: GBLS Functional Requirements

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 (WAD-GNSS, 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.

In clauses 6 and 7, the GBLS Architecture is defined hierarchically, starting in this clause with the top-level (Level 1) overall architecture. In clauses 6 and 7 the architecture is expanded into more detailed Level 2 and 3 architectures. The definitions in each case are of functional architectures. The Functional Elements (Blocks) required for the production of location-related data are defined, connected by logical interfaces which define information flows required between the functional blocks (not necessarily with any relationship to physical interfaces). In addition logical interfaces are also defined between the GBLS and any external elements. Figure 5-1 depicts the highest level GBLS architecture.

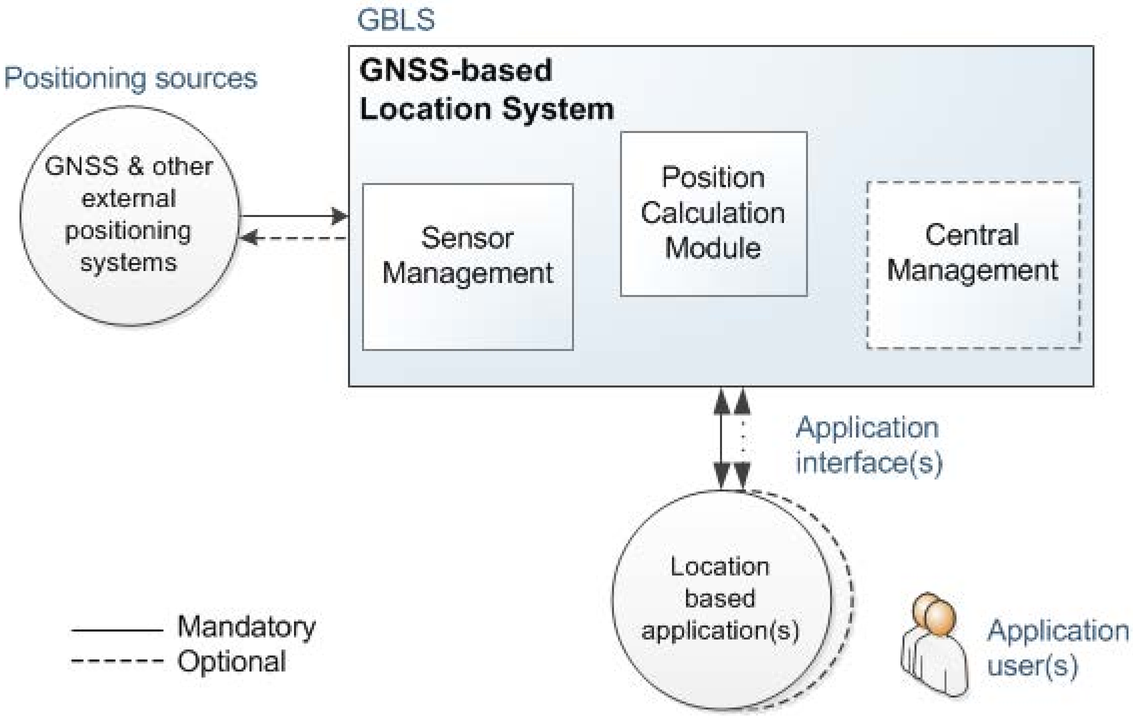


Figure 5-1: GNSS-based Location System (GBLS) Architecture (Level 1)

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 Requirement	GBLS Functional Block			
	Sensor Management	Position Calculation Module	Central Management	Application Interface Module
GNSS	X	X	(optionally)	
Multi-Sensor	X			
Hybridization		X		
Additional location data	X	X	X	
QoS indicator	X	X	X	X
M&C Interface				X
Availability	X	X	(optionally)	X
Priority				
Coverage	X			X
Latency	X			X
Security				X
Privacy			(optionally)	X
Service Authorization			(optionally)	X
Differential		X	(optionally)	
Assisted		X	(optionally)	

Mandatory
Optional

In clauses 5.2, 5.3 and 5.4, 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 this clause and in clause 5.2.1.2 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] and [15];
- GLONASS [6];
- Quasi-Zenith Satellite System (QZSS) [7];
- Indian Regional Navigation Satellite System (IRNSS) [8].

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

In addition there are regional non-autonomous GNSSs, designed as augmentation systems, aimed at enhancing the performance of global GNSSs with respect to availability, accuracy and integrity. Among them, the following regional GNSSs are supported in the present document:

- Satellite Based Augmentation Systems (SBAS), including WAAS, EGNOS, MSAS, and GAGAN.

Some augmentation systems related to GNSS are expected to provide additional external service:

- Commercial or institutional multi applications WAD-GNSS and (N)RTK, PPP, aeronautical D-GNSS service provider ([9], [11] and [12]).
- Assisted GNSS solutions.

5.2.1.2 Other External Systems

Other external systems may include:

- Terrestrial telecommunications networks providing position information (e.g. 3G, 4G, Wi-Fi®, etc.).

5.2.2 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.

In case the GBLS does not broadcast its location related data on a continuous basis, 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 attached to the target and to provide assistance data.
- Position Calculation that derives and issues the positioning and other parameters of a location target(s) from the sensor measurements, and possibly from the differential data coming from an external Differential GNSS service provider or coming from the Central Management.
- Central Management providing additional support functions, including, possibly, differential data services.

5.4 GBLS External Interfaces

The primary inputs to the GBLS are signals and data from GNSS and other sensors.

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

For D-GNSS, RTK and PPP solutions, RTCM 104 [9] and [11] should be applied for a direct compatibility.

For details of these interfaces see clause 7.2.

6 GBLS Architecture (Level 2)

6.1 Level 2 architecture mandatory and optional components

6.1.1 General

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

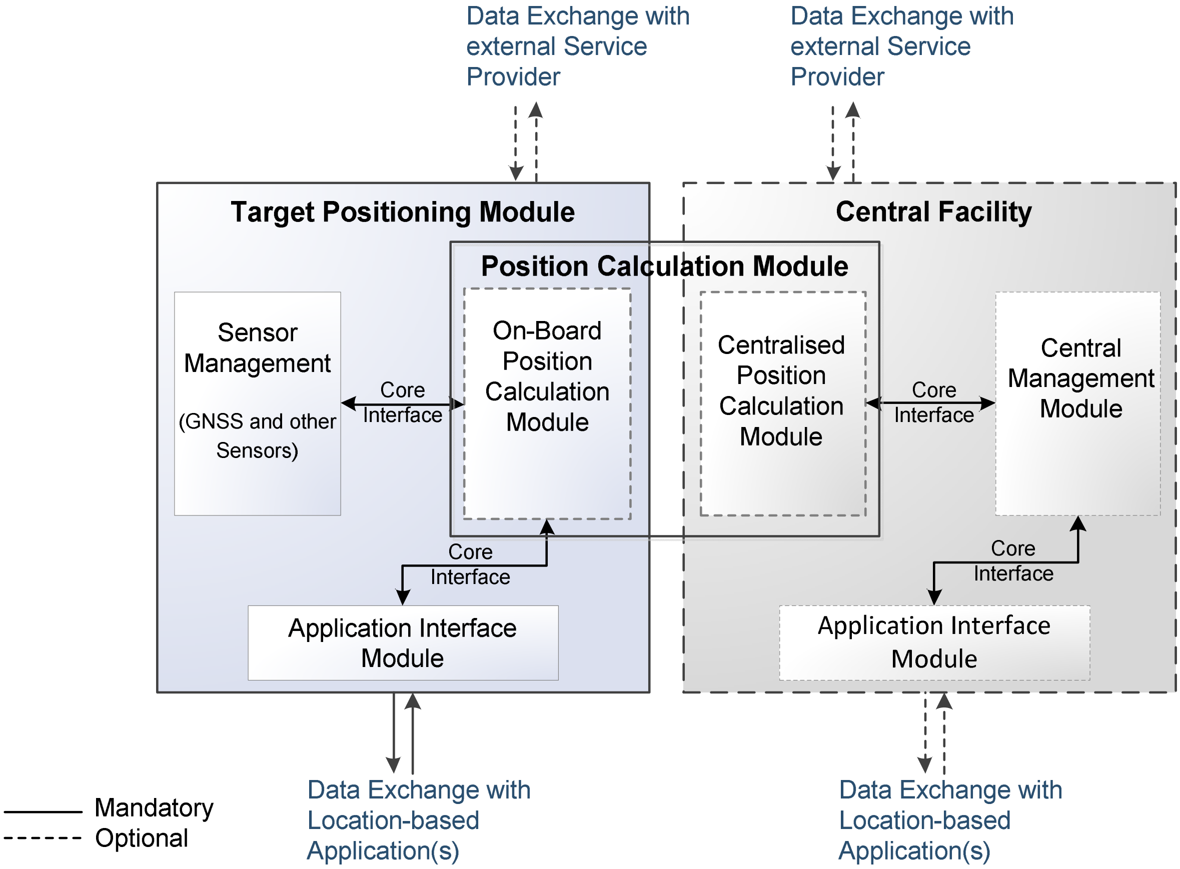


Figure 6-1: GBLS architecture (level 2) - Overall view

In this architecture level, Target Positioning Module (PM) and Central Facility (CF) architectures are defined. Both architectures are presented with their mandatory and optional modules or data exchanges.

The Position Calculation module from Figure 4-1 has been separated into two optional parts depending on the requirements of the system.

6.1.2 GBLS architecture with Target Positioning Module only

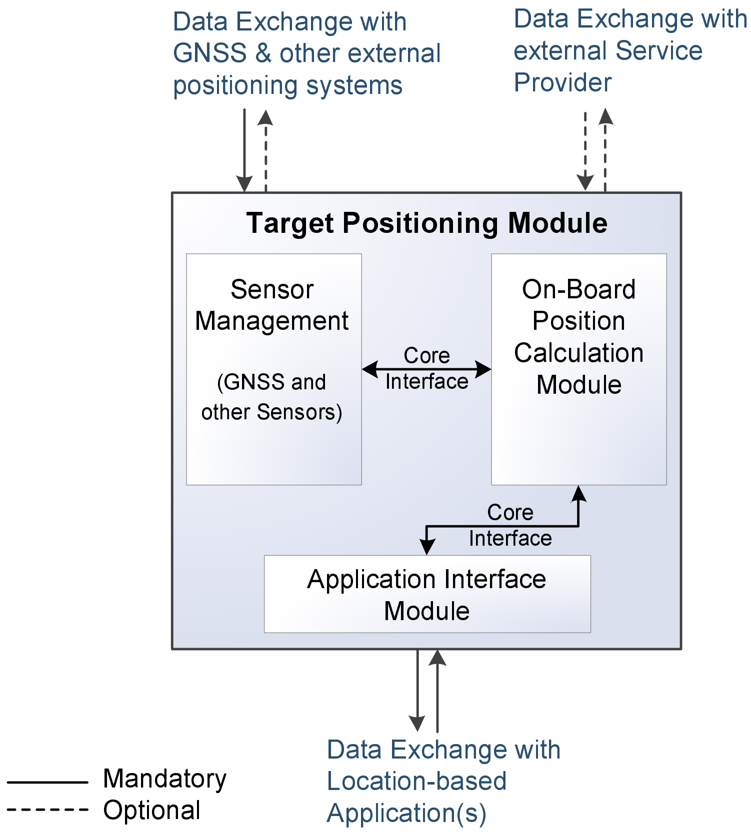


Figure 6-2: GBLS architecture (level 2) - Target Positioning Module only

In this architecture only a self-contained Target Positioning Module (PM) is required. Data exchanges result from a Positioning System or an optional External Service Provider available.

For example, this architecture reflects the case of a single location target such as a GNSS car receiver.

Examples of external service providers:

- Assisted GNSS.
- Differential GNSS (D-GNSS/RTK/PPP).

6.1.3 GBLS architecture with Target Positioning Module and Central Facility

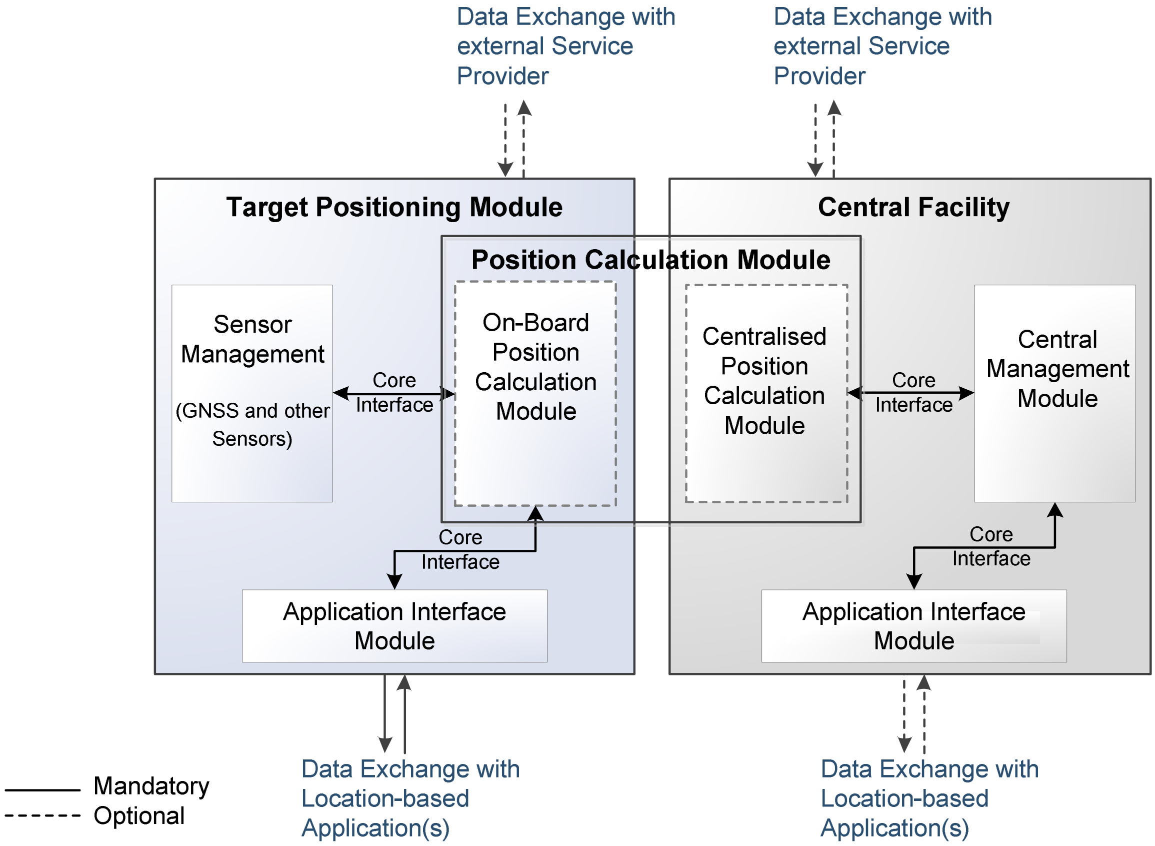


Figure 6-3: GBLS architecture (level 2) - Target Positioning Module and Central Facility (see text hereafter)

In this architecture, the Target Positioning Module (PM) and Central Facility (CF) are both mandatory. This architecture requires at least one Position Calculation module hosted by the PM or the CF. This module can also be shared between the two entities.

For example, this architecture reflects the case where a compact low-power remote PM is required together with a centrally located, more functional, CF (such as Alternative I-2 in Annex B).

The data exchanges with Location Based Applications via the Application Interface module can be done either by the PM or the CF. At least one Application Interface module may be present in the GBLS.

Table 6-1: GBLS mandatory and optional modules

Type of GBLS	Mandatory Module	Optional Module
Positioning Module Only	Sensor Management On-Board Position Calculation Module Application Interface Module	
Positioning Module and Central Facility	Sensor Management On-board Position Calculation Module or Centralized Position Calculation Module Central Management Module At least one Application Interface Module (from PM or CF side)	A second Application Interface Module A second Position Calculation Module

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 management function provides the interface between each sensor and the On-Board Position Calculation module including:

- sensor-to-sensor feedback (e.g. INS-aided GNSS tracking);
- the data encoding of sensor measurements to the Position Calculation module and vice-versa;
- the data encoding of support information (e.g. navigation message data, authentication flags) to the Position Calculation module and vice-versa.

6.2.2 On-Board Position Calculation Module (OBPCM)

The Position Calculation module consists of algorithms to process the measurements received from the sensors and produce location-related data.

These algorithms can be shared with the Centralized Position Calculation module in different ways:

- Allocated only to the On-Board module (e.g. for simple or self-contained systems).
- Allocated only to the Central Facility, when targets contain only sensors.
- Shared between both on-board and centralized functions (e.g. when an implementation needs to contain 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 according to the conditions specified by the request. It also manages the priority amongst the various requests received from one or several applications;
- 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.
- service authorization 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 Position Calculation Module (CPCM)

This Position Calculation module consists of algorithms that can be shared as defined in clause 6.2.2.

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 manage assistance data that the Position Calculation module may require in order to perform its position calculation 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 6.2.3).

6.4 Core Interface

The core interface manages all location data exchanges between:

- the sensors and the On-Board Location module;
- the Position Calculation module and the Application Interface module;
- the On-board Position Calculation module and the Centralized Position Calculation module;
- the Centralized Position Calculation module and the Central Management module.

The sensor interface to the Position Calculation module carries measurements from the sensors such as the GNSS and inertial units, amongst others. It also includes support data such as navigation message data (to allow navigation message authentication in the position calculation module) and authentication flags.

For details of these interfaces see clause 7.2.

7 GBLS Architecture (Level 3)

7.1 Level 3 detailed architecture

7.1.1 Generic GBLS

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

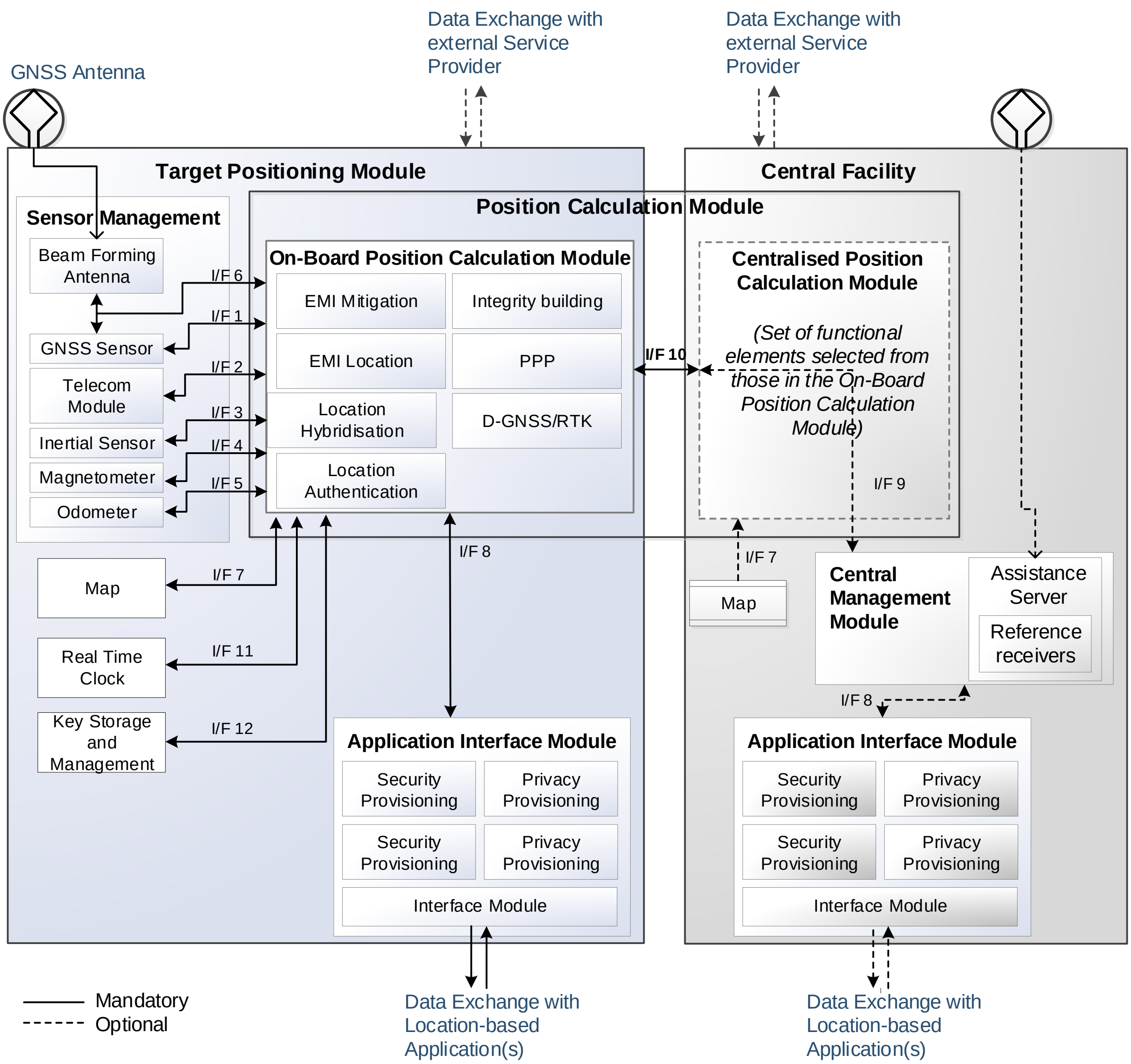


Figure 7-1: GBLS detailed architecture

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.

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 location algorithm;
- Location Hybridization Algorithm;
- Integrity building algorithm;
- PPP;
- RTK/D-GNSS;
- Location Authentication;
- Security Provisioning;
- Security Verification;
- Privacy Provisioning;
- Privacy Test;
- Interface module;
- Reference Receivers;
- Integrity Monitors;
- Assistance server;
- Map and data base;
- Real Time Clock;
- Key Storage and Management.

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. It determines the position of the location target by processing signals transmitted from space-based GNSS satellites at precisely known locations.

Specific GNSS authentication functions may be implemented within the GNSS sensor, these would still be considered as part of the "Location authentication" module even if implemented in another logic unit.

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 such as bases stations or WIFI access point) at fixed and precisely known locations.

The Telecommunication module may provide different types of measurements to the Position Calculation 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 positioning.

7.2.4 Inertial Sensor

The Inertial Measurement Unit (IMU) is an optional component of the Positioning module of the GBLS architecture. It 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 change 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. It 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 Position Calculation module if 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. It 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 Location

The Electro Magnetic Interference (EMI) location 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 location algorithm is responsible for determining the location-related data of RF interfering sources, transmitting over GNSS bands.

The EMI location algorithm includes an interference detector and a direction indicator that are used to estimate the location of the interference source. The EMI location 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 location may be achieved by processing measurements from separated sensors that would require the centralized Location module to perform the processing.

7.2.10 Location Hybridization Algorithm

The Location Hybridization Algorithm (LHA) is an optional component of the GBLS architecture. It is one of the algorithms responsible for determining the location-related data of a location target. It is specifically in charge of the processing required in the case that 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 position calculation 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. It 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 required in case a reliable quality of service indicator is required.

The Integrity Building Algorithm includes:

- An optional processing block and interface to GNSS sensor metrics (such as interference and multipath detection metrics). In this case these metrics produced by the GNSS receiver are compared to thresholds set according to the continuity and integrity risks and are then used, if necessary, 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 pseudorange 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. It provides precise estimates of the PVT by implementing algorithms able to mitigate most of the errors affecting GNSS positioning These errors include:

- 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 total electron content).
- 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 target GNSS sensor and data (i.e. precise ephemerides) from a PPP service provider, external to the GBLS.

7.2.13 D-GNSS/RTK processing 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. pseudoranges) generated by the GNSS sensor. Differential corrections sent by different augmentation systems can be received through the Application Interface. GNSS augmentation systems include:
  - SBAS (WAAS, EGNOS, Gagan, SDCM) broadcasting differential corrections on frequency bands allocated to GNSS.
  - Terrestrial data services, supporting ground-based access to SBAS differential corrections (e.g. EGNOS Data Access Service).
  - Terrestrial D-GNSS reference stations broadcasting differential corrections and satellite integrity flags on a dedicated wireless channel.
  - LAAS/GBAS aeronautical ground stations broadcasting differential corrections in the VHF band.
- 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 Position Calculation module receive:
  - Carrier phase measurements made by the on-board GNSS sensor (rover).
  - Position of the central facilities (base).
  - Carrier phase measurements made by the GNSS sensor installed at the central facilities (base).
  - Ancillary data used by the Positioning module to process the received augmentation data (e.g. datum conversion parameters, QoS indicators, etc.).

  RTK algorithms implemented within the Positioning module estimate the baseline between the rover and the reference station that is used to determine location-related data for 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.

  RTK data can be transmitted through a dedicated wireless channel (UHF, cellular, etc.).

RTCM 10403.2 [9] and RTCM 10402.3 [11] respectively provide comprehensive lists of D-GNSS and RTK augmentation data.

7.2.14 Location Authentication

The Location Authentication is an optional component of the GBLS architecture. It includes algorithms in charge of authenticating the position computed by the location target. The authentication may 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 may 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.
- Pseudorange and/or positions estimated by the GNSS sensor and set of measurements from other sensors (i.e. Inertial Sensor, Odometer, Magnetometer).

- Pseudorange and/or positions estimated by the GNSS sensor and set of measurements from the telecommunications module.
- Navigation Message data. Navigation messages can be digitally signed to ensure the authenticity of the data source and integrity. European GNSS system Galileo provides this capability with the OSNMA service (Open Service Navigation Message Authentication). OSNMA increases the robustness of the receiver against a number of GNSS threats. Note that OSNMA requires availability of a loosely synchronized trusted source of time (see clause 7.2.23).

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. It 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. It 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. It 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. It 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, pseudoranges, pseudorange 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 of either D-GNSS or RTK types (assuming the antenna is geo-referenced), and to monitor the quality of GNSS signals and compute D-GNSS integrity data.

7.2.21 Assistance server

The Assistance server is an optional component of the Central Facility of the GBLS architecture. It implements at least one of the following functions:

- Provision of A-GNSS data (assistance data as defined in ETSI TS 103 246-4 [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 WARTK data processing.
- Provision of correction data and satellite "do not use" flags for D-GNSS.
- Data preparation for D-GNSS.
- Interface with external service providers. Such an interface may 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 Map database (MD) is an optional component of GBLS architecture. It contains the digital map database with the graphical representation of all the spatial information required for route guidance. It is based on:

- single-line-road-network representing the centreline of the road; and a 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 optionally feeds the following blocks in the Position Calculation module:

- Location Hybridization Algorithm block in the 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.

7.2.23 Real Time Clock (RTC)

The Real time Clock (RTC) is an optional component of the GBLS architecture. It is essentially a crystal-oscillator clock with a backup battery allowing the propagation of current time even if the GBLS is switched off. Some authentication algorithms need an independent time source providing loose time synchronization to the algorithm. This is the case for Galileo OSNMA. The RTC is only needed in case alternative sources of timing are not available (e.g. from the Telecommunication module or the Assistance server). The RTC shall be available on the Positioning module.

7.2.24 Key Storage and Management (KSM)

The Key Storage is an optional component of the GBLS architecture. It is essentially a non volatile memory with key storage and, optionally, management capabilities. Depending on the type of application, it can require secure storage, tamper-proof and automatic wiping functions (in case physical tampering is detected).

This function is typically required by NMA algorithms. In particular, Galileo OSNMA requires storage of public material only (e.g. no need for wiping functions). The KSM shall be available on the Positioning module.

7.3 Interfaces

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

- I/F 1 GNSS Sensor to Position Calculation module

  GNSS sensors can provide a wealth of data in a variety of formats. This interface will allow RF samples, I/Q samples, pseudorange 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 Position Calculation module to the GNSS sensor over this interface. This interface supports time aiding, providing coarse time information to the GNSS module to shorten the time to first fix or to support authentication features, such as OSNMA.

- I/F 2 Telecommunication module to Position Calculation 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 Position Calculation module

  Reference frames may be established for the sensor orientation. 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.

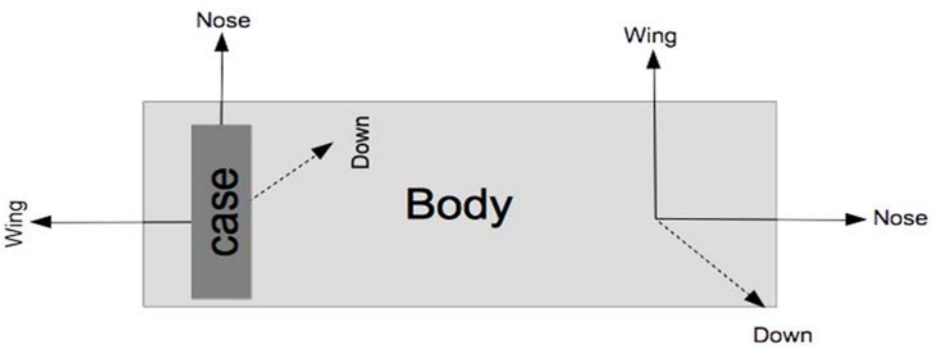


Figure 7-2: Sensor orientation reference frames

- I/F 4 Magnetometer to Position Calculation 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 Position Calculation 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 Position Calculation 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 Position Calculation module (e.g. EMI mitigation).

- I/F 7 Mapping Data to Position Calculation module

  The mapping data interface allows for the elements of the road network database to be provided to the Position Calculation 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 Position Calculation module. If there is no CMM in the CF, then this interface may be connected directly to the CPCM.

- I/F 9 Assistance or GNSS differential data Server to Position Calculation module

  The Assistance or RTK/D-GNSS server to Position Calculation module interface allows the exchange of request and responses of GNSS specific data and correction elements, such as orbit models, time, code, phase and pseudorange or GNSS differential data (an exhaustive list is provided in [9] and [11]).

- I/F 10 Position Calculation module to Position Calculation module

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

- I/F 11 RTC to Position Calculation module

  This interface is used to read/write current time and date from/to the RTC. The main blocks using RTC information are the GNSS sensor and the location authentication block.

- I/F 12 KSM to Position Calculation module

  This interface is used to load/store keys from/to the KSM. The main blocks using of KSM information are the GNSS sensor and the location authentication block.

Annex A:
Void

Annex B (informative): Specific case of GBLS using differential GNSS

B.1 Main use cases

If some improvement in accuracy is required for meeting the application requirements that are not met by a stand-alone GNSS receiver in the target, then differential GNSS techniques may be used in GBLS.

The present document attempts to cover both proprietary differential GNSS techniques or services integrate in the GBLS, as well as standardized differential GNSS services, for example those specified by the RTCM standards ([9], [11] and [12]).

It is important to separate in the functional architecture the GNSS sensors attached to the targets and the GNSS sensors used in the reference station(s) whose capabilities have only an indirect impact on the accuracy required by the GBLS customer. In the present document, the reference station is considered as an optional peripheral asset of the GBLS with its interface with the GBLS described in ETSI TS 103 246-4 [i.2], but it does not affect the performance requirements in ETSI TS 103 246-3 [i.6] or their verification defined in ETSI TS 103 246-5 [i.3].

A differential GNSS technique always requires a distributed physical architecture:

- at least one reference station, including at least one GNSS receiver, fixed at a known location;
- a rover GNSS receiver, which is necessarily attached to the target.

The differential GNSS service (providing differential GNSS data) can be:

- external to the GBLS (either an institutional or a commercial service);
- internal to the GBLS.

As a result, a number of different configurations of the architectures (either physical or functional) can be found.

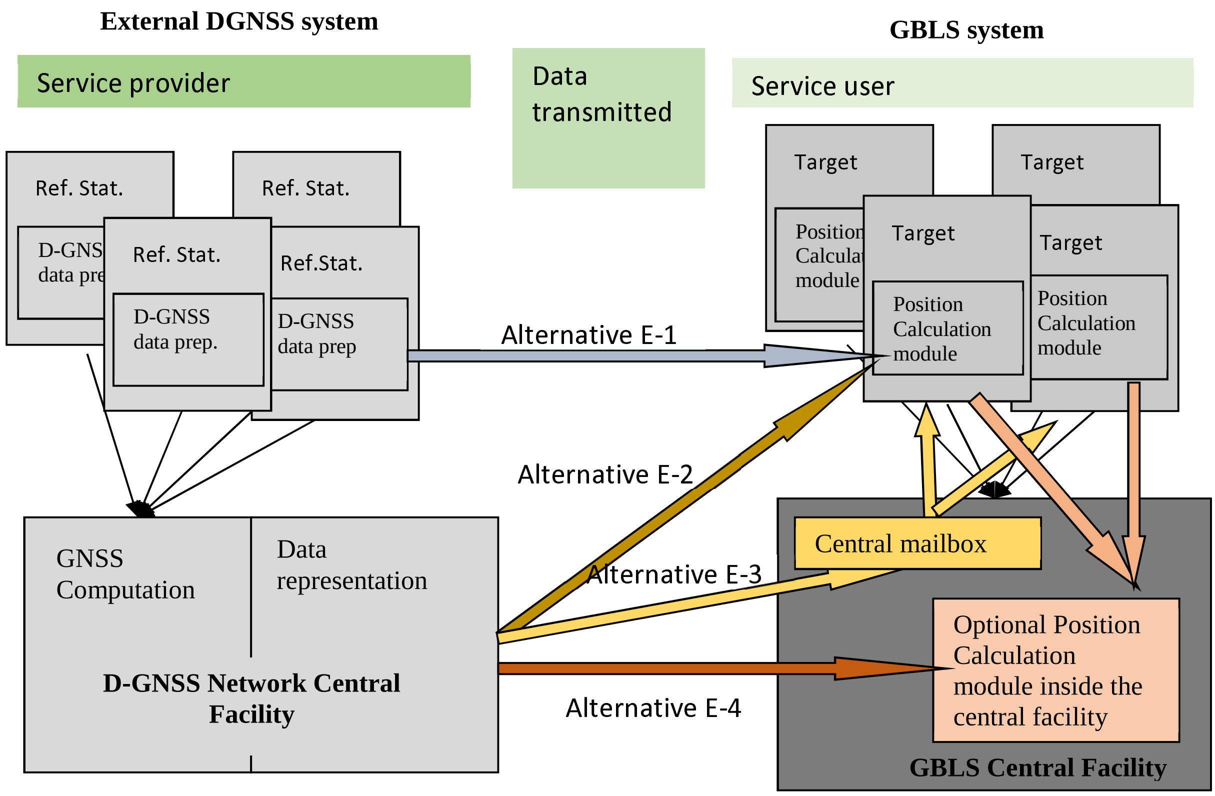


Figure B.1: Alternative configurations in the case of an external Differential GNSS service provider

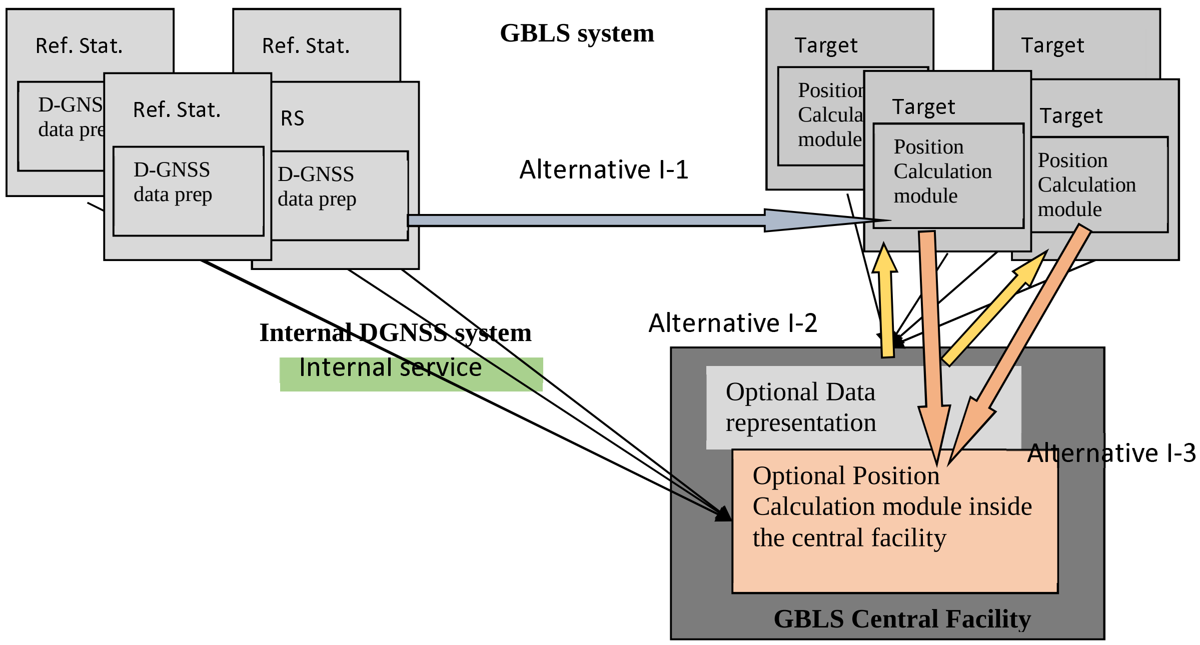


Figure B.2: Alternative configurations in the case of GBLS-operated differential services

Seven alternatives architectures are possible:

Alternatives in the case of an external Differential GNSS service provider:

- Alternative E-1: an external D-GNSS service provider is used by the GNSS receiver in the target with an individual data link managing the differential data exchanges (e.g. LAD-GNSS with either D-GNSS or RTK). In this case the preparation of differential data is external to the GBLS, the use of the differential data is inside the embedded Position Calculation module and the interface transferring the differential data is an external interface.

- Alternative E-2: an external networked D-GNSS service provider is used by the GNSS receiver in the target with or without (in the case of SBAS) an individual data link managing the differential data exchanges (in the case of NRTK and PPP). In this case the preparation of differential data is external to the GBLS, the use of the differential data is inside the embedded Position Calculation module and the interface transferring the differential data is an external interface.

- Alternative E-3: an external networked D-GNSS service is received by a common centralized data link in the GBLS Central Facility then sent (broadcast or point to multipoint) to be used by the GNSS receiver in the target. In this case the preparation of differential data is external to the GBLS, the use of the differential data is inside the embedded Position Calculation module and the interface transferring the differential data is in the first case an external interface and in the second case an internal interface.

- Alternative E-4: an external networked D-GNSS service is received by a common centralized data link in the GBLS Central Facility. In addition, the raw measurements are sent by the GNSS receivers embedded in the targets to the Central Facility (multipoint to point transfer) and both data flows are used inside an optional centralized Position Calculation module. In this case the preparation of differential data is external to the GBLS, the use of the differential data is inside the Central Facility and the interface for the differential data is in the first case an external interface and in the second case an internal interface.

Alternatives in the case of GBLS-operated differential services:

- Alternative I-1: isolated or networked reference station(s) are operated by the GBLS and provide the differential data through a data link (point to point or multi point to multi point) to the targets where the data is used by the embedded target GNSS receiver. In this case the preparation of differential data is internal to the GBLS (in an Assistance Server), the use of the differential data is inside the embedded Position Calculation module and the interface for the differential data is an internal interface.

- Alternative I-2: isolated or networked reference station(s) are operated by the GBLS and provide their differential data through a data link to the GBLS Central Facility. This latter routes the data to the embedded Position Calculation module through another data link. In this case the Central Facility centralized data and optionally provide specific error model (such as ionospheric corrections).
- Alternative I-3: isolated or networked reference station(s) are operated by the GBLS and provide their data through a data link to the GBLS Central Facility (multi point to point). Isolated or networked targets are operated by the GBLS and provide their raw measurements through a data link to the GBLS Central Facility (multi point to point). The Central Facility in the GBLS computes and directly uses the differential data for computing the location data of the targets. In this case the preparation of differential data is internal to the GBLS, the use of the differential data is inside the Central Facility.

Table B.1: D-GNSS alternatives data interfaces

Alternative	Differential Service Provider	Preparation of Differential Data	Use of Differential Data	Interface containing Differential Data
E-1	external GNSS system	external to GBLS	GBLS target's GNSS receiver	extern→target's GNSS receiver
E-2	external GNSS system	external to GBLS	GBLS target's GNSS receiver	extern→target's GNSS receiver
E-3	external GNSS system	external to GBLS	GBLS Position Calculation module	extern→Central Facility then Central Facility→Position Calculation module
E-4	external GNSS system	external to GBLS	GBLS Central Facility	extern→Central Facility
I-1	internal peripheral component	reference station GNSS receiver	GBLS target's GNSS receiver	reference station GNSS receiver→GBLS target's GNSS receiver
I-2	internal peripheral component	GBLS Central Facility	GBLS Central Facility then Position Calculation module	GBLS peripheral component→Central Facility→Position Calculation module
I-3	internal peripheral component	GBLS Central Facility	GBLS Central Facility	GBLS Central Facility→GBLS Position Calculation module

In the alternatives E-1 and E-2, the GNSS receiver in the target(s) should be directly standardized by one or more RTCM standards ([9] and [11]). Consequently only the other architectures will be considered in the present document.

In the other alternatives the Central Management module will always be the first entity that processes the differential data:

- If the differential GNSS service is provided by an external system, then the Central Facility at least contains the data link and either dispatches as is, the information to the target's GNSS receiver through a simple mailbox, or uses it itself to finalize the position calculation.
- If the differential GNSS service is integrated inside the GBLS Central Facility, then the Central Facility operates the reference stations and optionally prepares the differential data from the measurements issued from the reference stations. It then either dispatches it to the target's Position Calculation module or uses it itself to finalize the position calculation.

B.2 Impact on GBLS level 2 architecture

In the case where the GBLS implements a differential GNSS capability, as described in clause 5.3, several architectural alternatives are possible.

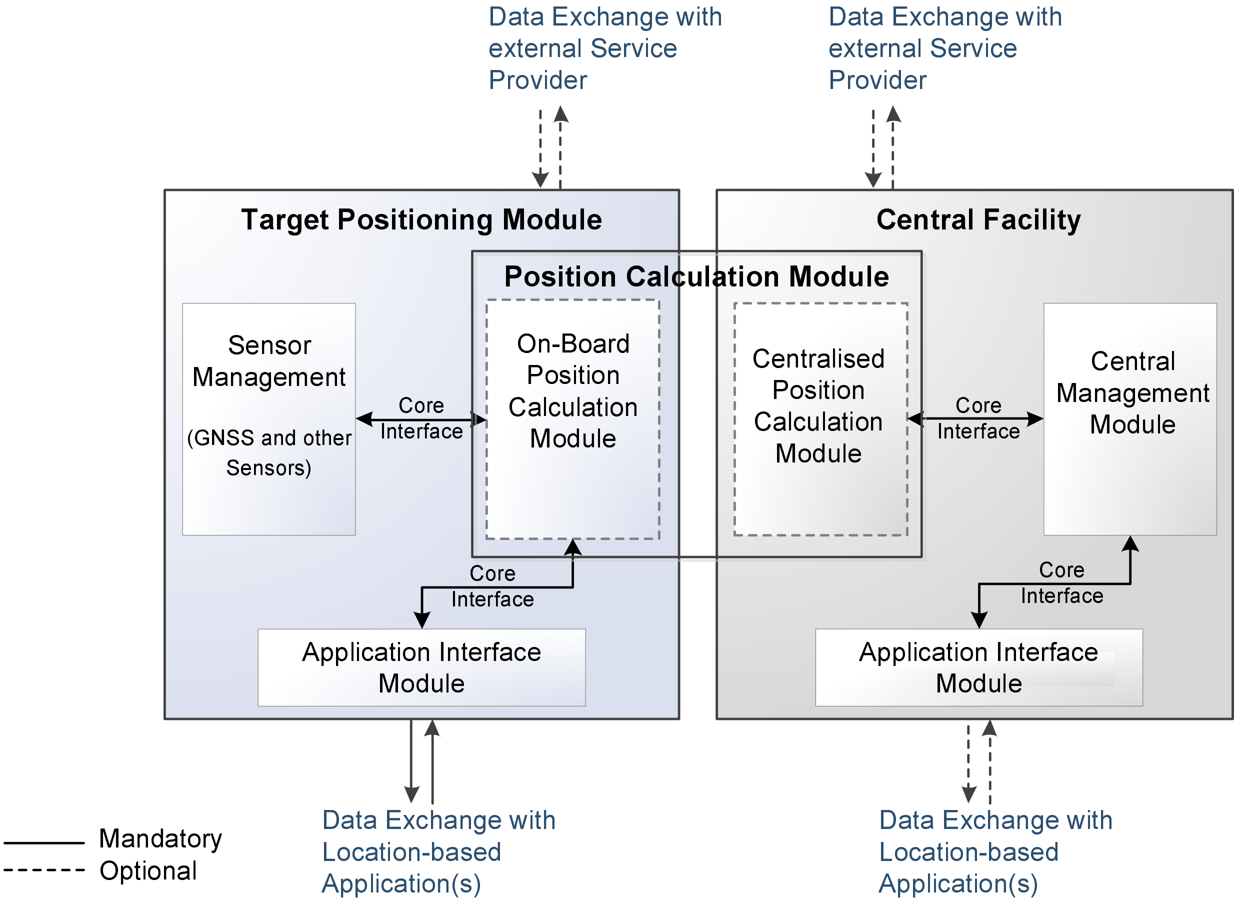


Figure B.3: GBLS architecture (level 2) - case of using differential techniques

- If the targets GNSS receiver is capable of using differential GNSS and the differential GNSS service is external (alternative E-1 and E-2), then no Central Facility is required dedicated to the differential GNSS method. In this case the RTCM standard ([9], [11] and [12]) are applicable to the targets GNSS receiver for the differential data.

- In other cases, a Central Facility is implemented, with possible optional functions depending on the architectural alternative:

  - Recovery of the differential data from an external differential GNSS service and routing it to the differential-enabled target's receivers (alternative E-3).

  - Use of the differential data coming from an external differential GNSS service in a centralized Position Calculation module and applying it to the raw measurements coming from the non-differential-enabled target's receivers (alternative E-4).

  - Operation of isolated or clustered differential reference stations, that will send the differential data to the differential-enabled target's receivers (alternative I-1).

  - Operation of isolated, clustered or networked reference stations, preparation of the differential data from measurements from their receivers, with additional optional integrity monitoring, and then send it to the differential-enabled target's receivers (alternative I-2).

  - Operation of isolated, clustered or networked reference stations, preparation of the differential data from measurements from their receivers, with additional optional integrity monitoring. This data is then used in a centralized Position Calculation module applying it to the raw measurements coming from the non-differential-enabled target's receivers (alternative I-3).

On-Board Position Calculation Module

Optionally, when differential GNSS techniques alternatives E-1, E-2, E-3, I-1 or I-2 are used and the target's receiver is enabled for these techniques, the selection of absolute/differential GNSS positioning mode is performed in the On-Board Position Calculation module. This selection depends on the availability of the differential GNSS data as well as on the differential GNSS solution used. This last computation depends on the nature of the differential GNSS method (D-GNSS, RTK, NRTK, PPP) and implements the corresponding algorithms as described in ETSI TS 103 246-1 [10], clause A.3.

Centralized Position Calculation Module

Optionally, when differential GNSS techniques alternatives E-4 or I-3 are used the selection of absolute/differential GNSS positioning mode is performed in the Centralized Position Calculation module. This selection depends on the availability of the differential GNSS data as well as on the differential GNSS solution used. This last computation depends on the nature of the differential GNSS method (D-GNSS, RTK, NRTK, PPP) and implements the corresponding algorithms (data use part) as described in ETSI TS 103 246-1 [10], clause A.3.

Central Management Module

Optionally, when differential GNSS technique alternative E-3 is used, the Central Management module controls the data link between the external differential GNSS and the GBLS and routes the differential data to the on-board Position Calculation module.

Optionally, when differential GNSS technique alternative I-2 is used, the operation and exchanges between the reference station(s) is performed in this module. In addition the preparation of the differential data is performed in this module depending on the availability of the differential GNSS data provided by the reference station and also depending on the nature of the differential GNSS method (D-GNSS, RTK, NRTK, PPP), it then implements the corresponding algorithms (data preparation part) as described in ETSI TS 103 246-1 [10], clause A.3.

Optionally, when differential GNSS technique alternative I-3 is used, the use of the standardized RTCM protocols [9], [11] and [12] is to be preferred between the on-board Position Calculation module and the Central Management module in order to maximize the compatibility with existing GNSS receivers. In future, this protocol could be enriched in order to add new innovative features, for example convergence between PPP and A-GNSS.

Core Interface

Optionally, the core interface carries the differential GNSS data, depending on the differential method used: SBAS/EDAS, D-GNSS, RTK, NRTK, PPP, as summarized in ETSI TS 103 246-1 [10], clause A.3.

B.3 Impact on GBLS Level 3 architecture

Depending on the functioning mode (terminal-assisted or terminal-based) and the alternatives in differential GNSS architectures and methods, some components of the on-board Position Calculation module and of the Central Facility are mandatory or not applicable. The following figure details the different configurations.

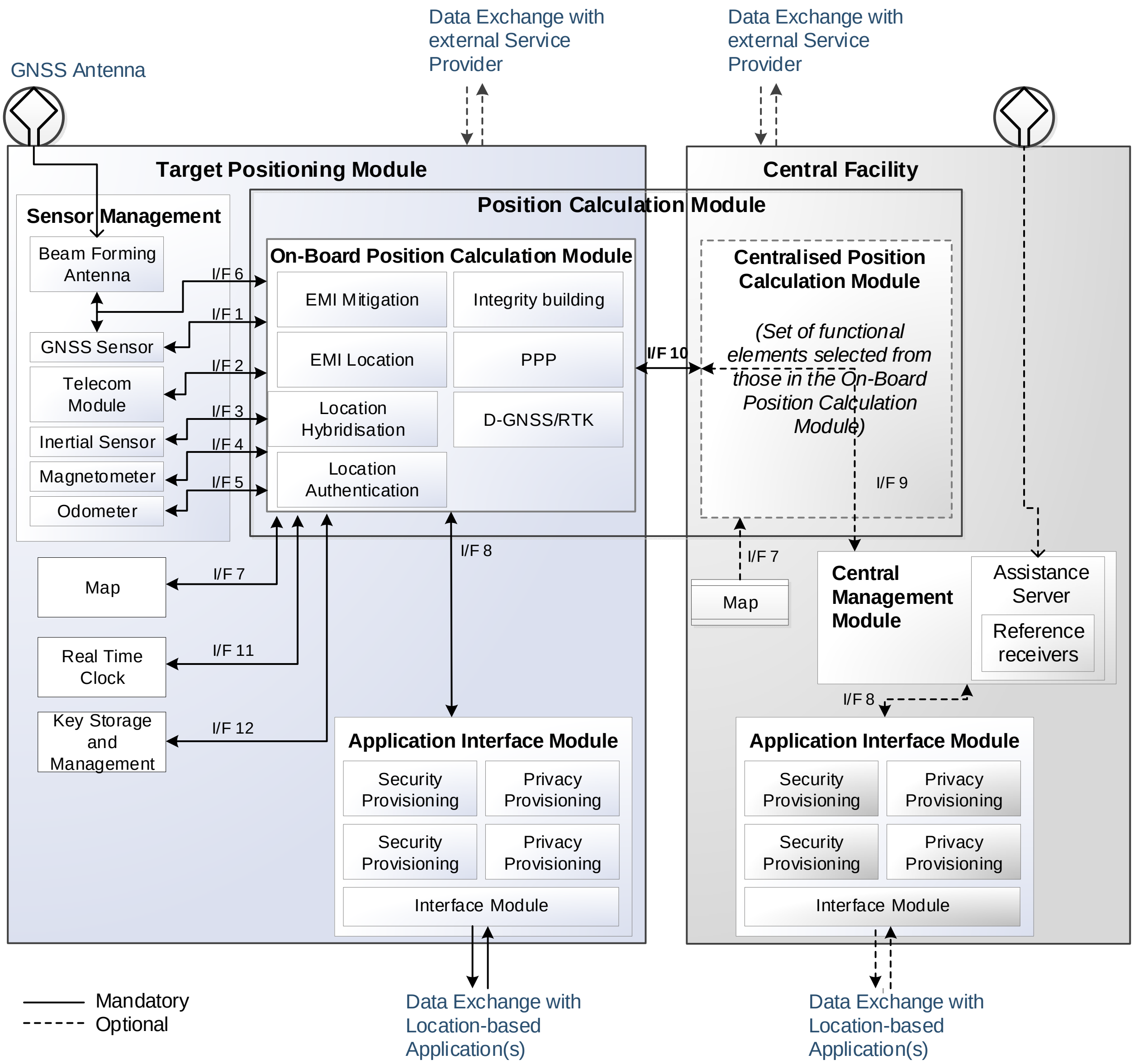


Figure B.4: GBLS architecture (level 3) - case of using differential techniques

Integrity Building algorithm

D-GNSS integrity as standardized by RTCM does not use the protection level concept. The Assistance Server (Reference Receiver and Integrity Monitor) only provides flags for faulty satellites through a "do not use" message sent to the location targets [12].

RTK as standardized by RTCM does not implement any GNSS integrity monitoring but only integrity checking of the data sent by the reference station to the location target through a CRC included in each message [13]. There is no Integrity Monitor coupled to the Reference Receiver in an RTK reference station.

GNSS Differential Data Use Module

The GNSS Differential Data Use module is an optional component of the GBLS architecture. It includes algorithms implementing at least one of the various GNSS differential methods as follows:

SBAS, EDAS, D-GNSS:

- Applying differential corrections on sets of measurements (i.e. pseudoranges) generated by the GNSS sensor before finalizing the positioning (PVT) result. Differential corrections sent by different augmentation systems can be received through the Sensor Management module. The GNSS augmentation systems include:
    - SBAS (WAAS, EGNOS, Gagan) broadcasting differential corrections on bands allocated to GNSS.
    - Terrestrial data services, supporting ground-based access to SBAS differential corrections (e.g. EGNOS Data Access Service).
    - Terrestrial D-GNSS reference stations broadcasting differential corrections and satellite integrity flags on a dedicated wireless channel.
    - LAAS/GBAS aeronautical ground stations broadcasting differential corrections in the VHF band.

RTK:

- Performing Real-Time-Kinematic (RTK) positioning. This requires the implementation of the RTK rover block within the Positioning module (on-board function, acting as rover).
- RTK rover algorithms implemented within the on-board Position Calculation module receive:
    - Carrier phase measurements generated by the on-board GNSS sensor (rover).
    - Position of the RTK reference station (as an external or GBLS facility).
    - Carrier phase measurements generated by the GNSS sensor installed in the reference station (base).
    - Ancillary data used by the Positioning module to properly process the received augmentation data (e.g. Datum conversion parameters, QoS indicators, etc.).
- RTK rover algorithms implemented within the Positioning module:
    - Compute the double differences between the rover and the base measurements in the first step, then between one line of sight and a pivoting line of sight.
    - Resolve the floating or integer ambiguities of wavelength on these double differences.
    - Estimate the baseline between rover and the reference station that is used to determine location-related data of the location target.
- RTK positioning can be also be performed with GNSS sensors installed on two (or more) different Positioning modules, one acting as rover, the other(s) as base (relative positioning or attitude determination).

  RTK base to rover data can be transmitted through a dedicated wireless channel (UHF, GSM, GPRS, UMTS, LTE, etc.).

NRTK-VRS:

- Performing Network Real-Time-Kinematic (NRTK) positioning by the VRS method. This requires the implementation of the NRTK-VRS rover block within the Positioning module (on-board function, acting as rover) and the elaboration and sent of a request to the GNSS differential service provider (either external or internal) providing its own approximate location.
- NRTK-VRS rover algorithms implemented within the on-board Position Calculation module receive:
    - Carrier phase measurements generated by the on-board GNSS sensor (rover).
    - Position of the virtual RTK reference station (as setup by the GNSS differential service provider, an external or GBLS facility).

  - Carrier phase measurements computed (by extrapolation) for the VRS.
  - Ancillary data used by the Positioning module to properly process the received augmentation data (e.g. Datum conversion parameters, QoS indicators, etc.).

- NRTK-VRS algorithms implemented within the Positioning module:
  - Compute the double differences between rover and VRS measurements in the first step, then between one line of sight and a pivoting line of sight.
  - Resolve the floating or integer ambiguities of wavelength on these double differences.
  - Estimate the baseline between rover and the VRS that is used to determine location-related data of the location target.

  NRTK-VRS data can be transmitted through a dedicated wireless channel, including a two way capability (UHF, GSM, GPRS, UMTS, LTE, etc.).

NRTK-FKP:

- Performing Network Real-Time-Kinematic (NRTK) positioning by the FKP method. This requires the implementation of the NRTK-FKP rover block within the Positioning module (on-board function, acting as rover).
- NRTK-FKP rover algorithms implemented within the on-board Position Calculation module receive:
  - Carrier phase measurements generated by the on-board GNSS sensor (rover).
  - Positions of the nearest RTK reference stations (as operated by the GNSS differential service provider, an external or GBLS facility).
  - Carrier phase measurements generated by the GNSS sensor installed in the nearest reference stations (base).
  - Complementary data (FKP correction) for extrapolating corrections to base measurements from one station to another.
  - Ancillary data used by the Positioning module to properly process the received augmentation data (e.g. Datum conversion parameters, QoS indicators, etc.).
- NRTK-VRS rover algorithms implemented within the Positioning module:
  - Compute the double differences between rover and bases measurements in the first step then between one line of sight and a pivoting line of sight.
  - Correct these observations by the FKP correction parameters.
  - Resolve the floating or integer ambiguities of wavelength on these double differences.
  - Estimate the baseline between rover and the nearest bases that is used to determine location-related data of the location target.
- NRTK-FKP data can be transmitted through a dedicated wireless channel (UHF, GSM, GPRS, UMTS, LTE, etc.).

NRTK-MAC:

- Performing Network Real-Time-Kinematic (NRTK) positioning by the MAC method. This requires the implementation of the RTK block within the Positioning module (on-board function, acting as rover).
- NRTK-MAC algorithms implemented within the on-board Position Calculation module receive:
  - Carrier phase measurements generated by the on-board GNSS sensor (rover).

    - Positions of the sub networked RTK reference stations, geodetic for the master reference station of the subnetwork, relative to the master for the auxiliary reference station (as operated by the GNSS differential service provider, an external or GBLS facility) and other information for identifying a subnetwork.
    - Carrier phase measurements generated by the GNSS sensor installed in the master reference stations (master base).
    - Ambiguity levelled simple difference of carrier phase measurements generated by the GNSS sensors installed in the master and in the auxiliary reference stations separated into two groups: a dispersive one (ionospheric) and a non dispersive one (geometric).
    - Ancillary data used by the Positioning module to properly process the received augmentation data (e.g. Datum conversion parameters, QoS indicators, etc.).

- NRTK-MAC algorithms implemented within the Positioning module:
    - Compute the double differences between rover and the bases measurements (both master and auxiliary) in the first step, then between one line of sight and a pivoting line of sight, correcting the auxiliary computations by the ionospheric and tropospheric corrections.
    - Resolve the floating or integer ambiguities of wavelength on these double differences.
    - Estimate the baselines between rover and the various bases that are used to determine the location-related data of the location target.
- NRTK-MAC data can be transmitted through a dedicated wireless channel (UHF, GSM, GPRS, UMTS, LTE, etc.).

Precise Point Positioning - PPP:

The PPP module provides precise estimates of the PVT, implementing algorithms able to mitigate, thanks to a set of GNSS differential data called Space State Representation (SSR) 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].

This requires the implementation of the PPP block within the Positioning module (on-board function, acting as rover).

- PPP algorithms implemented within the on-board Position Calculation module receive:
    - Carrier phase measurements and pseudorange measurements generated by the on-board GNSS sensor (rover).
    - The SSR set of corrections.
    - Ancillary data used by the Positioning module to properly process the received augmentation data (e.g. Datum conversion parameters, QoS indicators etc.).
- PPP algorithms implemented within the Positioning module:
    - Compute undifferentiated but corrected by SSR pseudorange and carrier phase measurements.
    - Resolve simultaneously the floating or integer ambiguities of wavelength on the carrier phase measurement and the PVT that is used to determine location-related data of the location target.
- PPP data can be transmitted through a dedicated wireless channel (UHF, GSM, GPRS, UMTS, LTE, etc.).

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 ephemeris) from a PPP service provider.

RTCM 10403.2 [9] and RTCM 10402.3 [11] provide a comprehensive list of D-GNSS, RTK, NRTK and PPP differential data.

WAAS performance standard [13] and RTCA DO-229D [14] provide a comprehensive list of SBAS and EDAS augmentation data (both differential and integrity).

On site or remote Reference Receivers

Reference Receivers are optional components of the GBLS architecture. They are GNSS sensors 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, pseudoranges, pseudorange 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 of either D-GNSS or RTK types (assuming the antenna is geo-referenced), and to monitor the quality of GNSS signals and compute D-GNSS integrity data.

They can also be networked to be used to generate wide area differential corrections of either NRTK or PPP types.

RTCM 10401.2 [12] provides an exhaustive list of data and requirements for D-GNSS reference stations. [9] provides an exhaustive list of data and requirements for NRTK or PPP reference stations.

GNSS Differential Data Preparation module

When a GNSS differential technique is required to meet the high accuracy demands of an application, and when an internal-to-GBLS GNSS differential service provider is preferred to using an external service provider, a GNSS Differential Data Preparation module is required. This is used to recover and gather the raw measurements and data from one (or a network of) reference station(s), and also to compute the differential data to be supplied as input to the GNSS differential data use. Clause 7.2.13 contains a detailed list of this data according to the differential method used. RTCM 10403.2 [9] provides an exhaustive list of data and requirements for computing this data to be used in RTK, NRTK or PPP. RTCM 10402.3 [11] provides an exhaustive list of data and requirements for computing this data to be used in D-GNSS.

GNSS Differential Data Routing module

When a number of targets are involved in the GBLS in a local area, embedding GNSS receivers and on-board Position Calculation modules allows the application of one or more GNSS differential techniques. For this a simple communication module, a GNSS Differential Data Routing module, is required and a design with the GBLS using a Central Management module is preferred. This GNSS Differential Data Routing module is equipped with a common datalink (for example using UHF or internet protocol using NTRIP) which collects (and maybe prepares and/or reformates) the GNSS differential data before dispatching it, (through a subscription possibly) to each target's GNSS sensor.

Integrity Monitor

The Integrity Monitor (IM) is an optional component of the GBLS architecture and complementary to the Reference Receiver installed at the Central Facility for provision of a D-GNSS service [11] and [12].

The IM uses an additional GNSS reference receiver and compares the correction data broadcast by the Reference Station with the received GNSS signals. If one or several corrections applicable to a satellite are beyond a predefined threshold the IM alerts the Reference Station which checks the related corrections and either sends new correction data or flags the related satellite with a "do not use" message. By design this process also monitors the integrity of the data broadcast on the telecommunications link.

RTCM 10401.2 [12] provides an exhaustive list of data and requirements for Integrity Monitoring.

Table B.2: D-GNSS alternatives minimum services

Alternatives	Differential Data used	Integrity Monitoring	On-site or remote Reference Receiver(s) operation	Differential Data preparation	Differential Data routing
E-1 External D-GNSS (D-GNSS or RTK) D-GNSS/RTK terminal-based	Mandatory in OBPCM	Mandatory in OBPCM when standardized D-GNSS	N/A	N/A	N/A
E-2 External D-GNSS (EDAS, NRTK or PPP) EDAS/NRTK/PPP terminal-based	Mandatory in OBPCM	Optional in OBPCM. Can use EDAS information	N/A	N/A	N/A
E-3 External D-GNSS (all) differential terminal-based	Mandatory in OBPCM	Mandatory in OBPCM when standardized D-GNSS. Optional otherwise. Can use EDAS information	N/A	Optional (computation of new representation is feasible)	Mandatory
E-4 External D-GNSS (all) differential terminal-assisted	Mandatory in CPCM	Mandatory in CPCM when standardized D-GNSS. Optional otherwise. Can use EDAS information	N/A	Optional (computation of new representation is feasible)	N/A
I-1 Internal D-GNSS (D-GNSS or RTK) D-GNSS/RTK terminal-based	Mandatory in OBPCM	Mandatory in OBPCM when standardized D-GNSS	Mandatory	N/A (assumes that the process is done inside the reference stations)	Mandatory
I-2 Internal D-GNSS (EDAS, NRTK or PPP) EDAS/NRTK/PPP terminal-based	Mandatory in OBPCM	Optional in OBPCM. Can use EDAS information	Mandatory	Mandatory	Mandatory
I-3 Internal D-GNSS (all) +differential terminal-assisted	Mandatory in CPCM	Mandatory in CPCM when standardized D-GNSS. Optional otherwise. Can use EDAS information	Mandatory	Mandatory	N/A

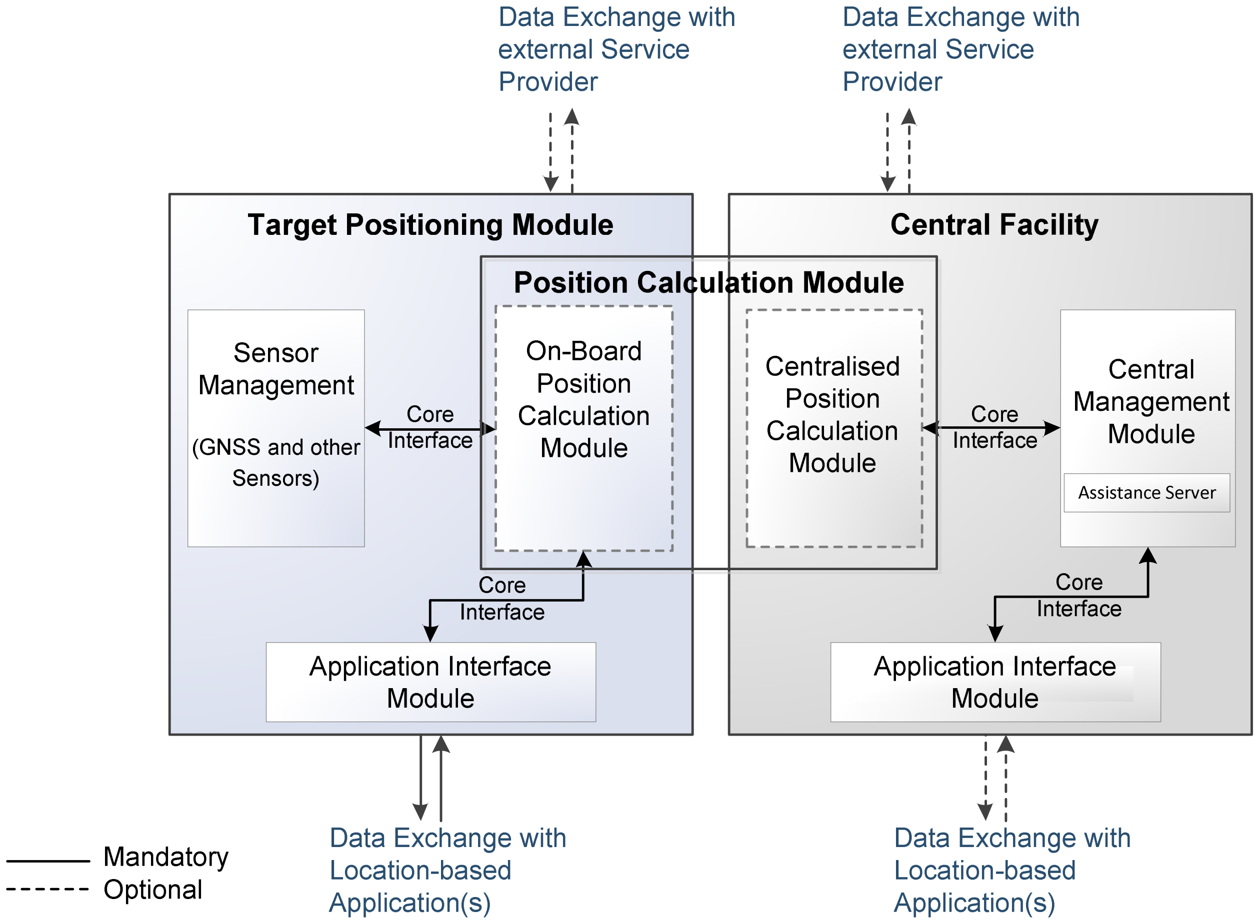
Initially applied in a local area by using a single reference station, this technique is now mostly developed with networked reference stations (NRTK). Under the NRTK term, several different techniques for data exchanges have been developed using either one way or two way communications.

The ambiguities affecting the carrier phase measurements are, by definition, an integer number of carrier wavelengths. Depending on the accuracy of the estimation of the systematic errors in the GNSS measurements provided by the differential technique, which depends itself on the range between the reference station and the rover, the ambiguity resolution process can resolve this integer number of wavelengths (integer RTK) or an approximate floating value of the integer number (floating RTK). Floating RTK gives typically decimetre accuracy while integer RTK gives typically centimetre accuracy.

Annex C (normative): Assisted GNSS architectures

C.1 Impact on GBLS level 2

In the case where the GBLS implements an A-GNSS capability, a Central Facility with an Assistance Server is required. This assistance server contains a dedicated GNSS reference receiver (see clause 7.2.20).



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

Figure C.1: GBLS architecture (level 2) - option A-GNSS

It is possible that the 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.

Core Interface:

Optionally, the core interface also provides feedback to the sensors, for example assistance data that may be generated from the processing of sensor data or provided via the interface to the assistance server. The core interface between the sensors and the Position Calculation 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 Position Calculation module for off-sensor processing of raw GNSS data.

Table C.1 indicates where the processing for various (A-)GNSS techniques takes place as a function of the supported mode.

Table C.1: Location service requests for A-GNSS

	Supported Mode		
Processing step	**A-GNSS Terminal-assisted**	**A-GNSS Terminal-based**	**GNSS Standalone**
Baseband processing	Positioning Module	Positioning Module	Positioning Module
Pseudo range calculation	Positioning Module	Positioning Module	Positioning Module
Position calculation	Central Facility	Positioning Module	Positioning Module
Decoding of Satellite data	Central Facility	Central Facility	Positioning Module
Selection of Satellites	Central Facility	Central Facility	Positioning Module

Annex D (informative): OSNMA within GBLS

D.1 Implementation options

This Annex provides an overview of possible implementation option for OSNMA within the GBLS. The following figure shows that three options are available to integrate OSNMA processing:

- Within the GNSS sensor.
- Within the On-board Position Calculation Module.
- Within the Centralized Position Calculation Module.

The implementation within the GNSS sensor is considered the baseline approach, however other strategies may be defined to accommodate specific implementation profiles.

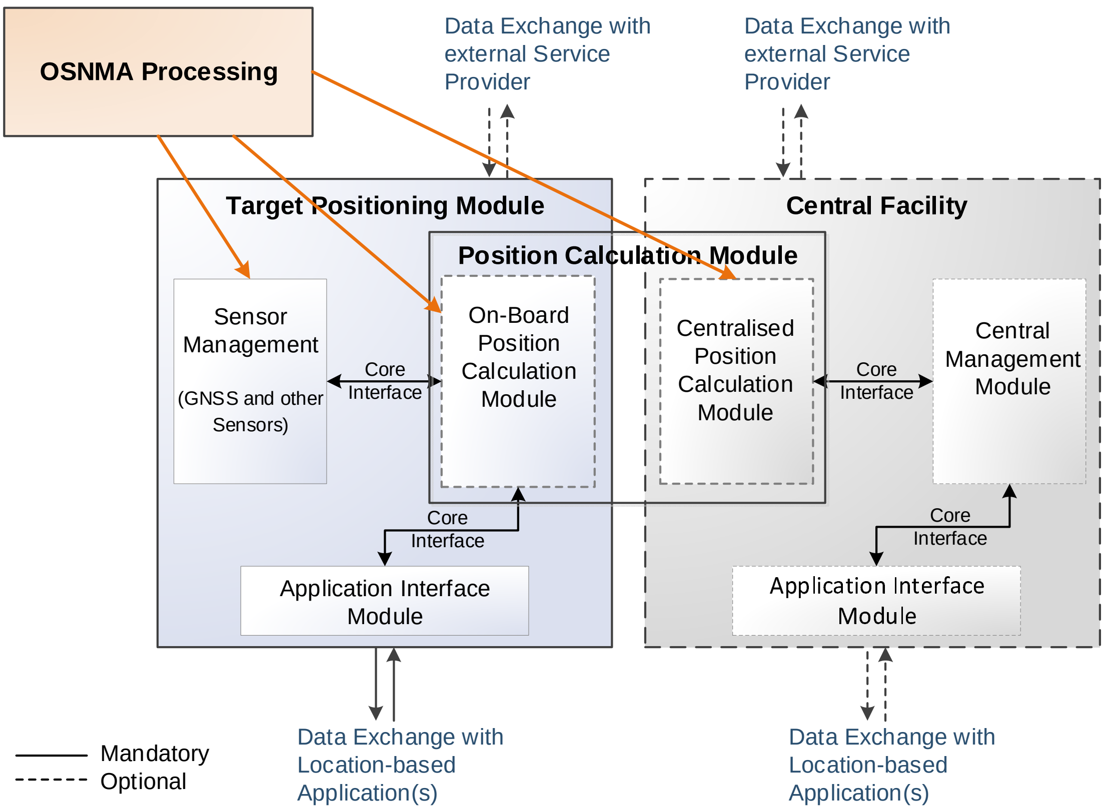


Figure D.1: OSNMA processing options

The different integration approach impact mainly:

- Security requirements (KSM need, etc.).
- Performance requirements of the equipment (terminal side or central facility, as well as GNSS chipset – CPU, memory etc.).
- Authentication performance requirements (particularly Time-To-First-Authenticated-Fix (TTFAF), Authentication frequency, etc, mode of operations).
- Interface bandwidth requirements.

Annex E (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
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