

# Pushing standardisation of GNSS-based Location Systems to support Terrestrial Applications development

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## BIOGRAPHIES

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## ABSTRACT

The expansion of terrestrial applications including location-based services and transportation means such as road or train has fostered the design of complex location systems to comply with the needs of these applications. In the frame of the service provision ensured by the application towards a user or an external entity, these location systems are in charge of providing a consolidated information based on the position of one or more mobile platforms.

The complexity of the information reported depends on the type of service targeted. It can range from a simple position reporting in the case of a low end asset management, to the provision of a reliable information

(e.g. authenticated and with a mastered uncertainty) on the mobile's trajectory for liability critical services such as road charging or Intelligent Transport System (ITS).

This wide spectrum of required technical features calls for a new and broader concept at location system level taking into account hybrid solutions in which the use of GNSS technologies is complemented with other technology sensors to improve the robustness and the performance of the solution.

Several standards have been generated by different dedicated bodies, in order to support the GNSS market development across the various application domains mentioned above. For instance, 3GPP Location Services (LCS) standards provide minimum performance requirements mainly for Assisted-GNSS in the frame of terrestrial telecommunications and OMA-LOC LPPE (LTE Positioning Protocol Extensions) defines a communication protocol supporting hybridised positioning.

Nevertheless, there is still a lack of performance specification for a large number of terrestrial applications (e.g. electronic fee collection, fleet management, container tracking ...), including multi-modal applications (i.e. those involving various means of transport), leading to the development and use of sub-optimal GNSS-based systems and solutions.

The need to unify the different initiatives by concentrating the positioning-related standardisation effort for terrestrial applications within a single dedicated entity was identified some time ago

Accordingly, an initiative triggered by a number of industrial and institutional stakeholders materialized in the frame of the European Telecommunications Standards Institute (ETSI). This initiative is led by the group Satellite Communication and Navigation (SCN) of the Technical Committee Satellite Earth Stations and Systems (TC SES), the main objective being to elaborate a firm and common standard for GNSS-based Location systems. Up to now, the TC-SES has already approved end of 2012 two Technical Reports related to architectures and application inventory which paved the way for the technical specifications to be developed.

The present paper provides an overview of this on-going standardisation work, its objectives and the added-value it will bring. In addition, the already approved Technical Specifications will also be presented.

Thus, the structure of the targeted standard encompasses the four following specifications:

- The location system minimum performance requirements, which can be considered as the core of the specification work. These requirements are determined function of the type of location systems (i.e. association of technical enablers), the applicable

environmental conditions (depending on the type of application), and finally the type of features needed (e.g. accuracy, authentication, anti-spoofing, robustness to interference).

- The GNSS-based location system reference architecture including the interface definition, which is expected to capture a generic and modular definition of location systems, thus adaptable to all targeted applications.
- The data exchange protocol at location system level (covering in particular the handling of the requests from an external application provider and the protocol to ensure proper information delivery).
- The test specification (including procedure, scenario and data), enabling location system validation versus the previous requirements (protocol and performance).

The methodology used to define the perimeter of the above specifications looks for:

- The definition of terrestrial application classes to be covered by the standard, including the identification of the key requirements (functional and performance) applicable for each application.
- The inventory of the technological enablers taken on-board in the standard. These enablers are understood as much as sensor technologies (GNSS receivers, Network sensors, inertial sensors, hybridization layer), as system layer features allowing Quality of Service (QoS) improvements (A-GNSS, D-GNSS, RTK, integrity functions, authentication functions).
- The definition of reference environments, derived from the applications' typical use cases, and which provide the necessary conditions to determine the minimum performance requirements.

With the ambition to satisfy a wide range of terrestrial applications, the standard under preparation, once approved, will surely benefit to other standardization groups. Indeed, care is being taken to harmonize the work done under TC SES SCN, with standardisation groups in other domains. Furthermore, it will also be valuable to actors from markets whose specificities do not justify the existence of a dedicated standard. All these stakeholders will thus benefit from a more important variety of solutions, components and functions available, all of them simultaneously compatible to the standard.

## **INTRODUCTION**

### **BACKGROUND AND OBJECTIVES**

#### **European Policy and Market Overview**

Seamless and sustainable mobility of persons and goods are decisive conditions to meet the major objectives of the EU transport policy, notably more efficient exchanges in the Single Market, greener transport modalities and improved economic and societal transport aspects for the service to EU citizens.

For many years the European Union has been deploying huge efforts to pave the way for safer, cleaner and sustainable, more interoperable, secure, efficient and competitive transport systems. EU initiatives and policies, such as Intelligent Transport Systems (ITS)<sup>1</sup>, Single European Sky Air traffic management Research (SESAR), European Rail Traffic Management System (ERTMS), e-Freight, and European Single European transport area or Trans-European Transport Networks (TEN-T), will show this will to create pan-European networks, infrastructures and information flows necessary to meet these policy objectives.

The creation of such a European mobility network requires first innovation and standardisation to ensure the efficiency and interoperability of transport support systems. In particular, this network must deploy large scale intelligent and interoperable technologies in each transport domain (air, maritime and inland waterways, road, rail, multimodal and pedestrian) to optimise capacities and use of the infrastructure while avoiding technological fragmentation detrimental to the global interoperability and performance of the transport market.

Answering to this main challenge, the EU is creating the framework conditions to promote the development and use of intelligent and interoperable systems. The development of European standards is key to support the implementation of these European flagship policies.

These conditions apply to the development of GNSS applications and services, more specifically to the development of GNSS-based terrestrial applications since GNSS technology is one of the key technologies able to meet interoperability requirements in all transport domains and is available anywhere at any time all over the world. To this end the EC and its agencies, including GSA have deployed considerable efforts in the different application fields (civil aviation, maritime, rail, road, LBS) through application development projects and support to standardisation.

The expansion of terrestrial applications including location-based services in transportation modes like road or rail has indeed fostered the design of complex location systems and services sometimes requiring compliance with safety and reliability requirements (e.g. road user charging, advanced driver assistance systems). A large field however remains for mass market LBS applications with less stringent requirements but with strong needs for interoperability and harmonized performance which are decisive features for market uptake in this domain.

The following figure illustrates the GNSS market shares by segment:

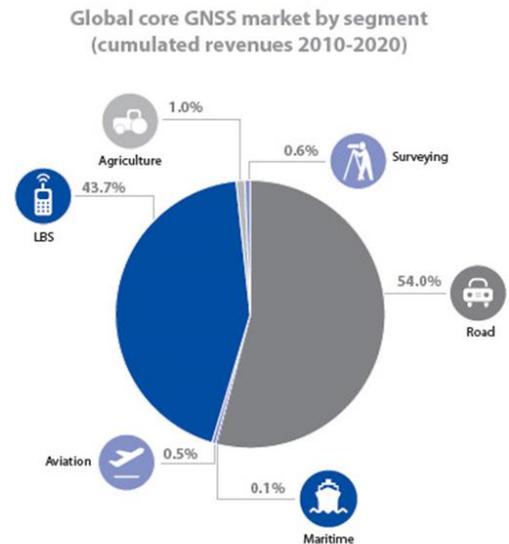


Figure 0: Core GNSS market by segment<sup>2</sup>

The potential markets for GNSS-based Location Systems in terrestrial applications represent the biggest share of GNSS applications market (nearly 95% in both volume and revenues according to "Action Plan on Global Navigation Satellite System (GNSS) Applications" – see [1]; close to 99% of the 2010-2020 cumulated revenues from the worldwide GNSS market according to GSA Market Report issue 2).

Other markets like aviation and maritime should not be neglected as the operational, safety and environmental benefits already demonstrated in these sectors are very significant.

So the question might be why such benefits are not yet or insufficiently tangible in road and LBS domains. Among answers of different nature we have to highlight the lack of GNSS standardisation, conversely to aviation and maritime sectors which have a long standardisation storyboard behind them.

A wide range of existing and potential user-oriented applications for location-based systems could be enabled and developed by the market if there were a better, more consistent, more fundamental and complementary basis to the standards in this domain. By promoting the development of GNSS use and technologies, the EU leverages on standardisation actions to facilitate the work of application developers and foster the innovative market of location services.

European standards are needed to give confidence to industry to enable them to further develop and invest in products that will be accepted by the market and will be interoperable with other system components produced elsewhere. In this way the market will be developed more quickly and competitively as a wider range of applications will be addressed.

<sup>1</sup> "Intelligent Transport Systems" - Source: EC COM(2008) 886

<sup>2</sup> Source : GNSS Market Report issue 2 – GSA 2012 - <http://www.gsa.europa.eu/market/market-report>

They should facilitate pan-European applications deployments that could contribute to the EU Internal Market and competitiveness objectives.

### **Existing Standardization Frameworks**

Regarding the development of GNSS standards for services and user equipment in the specific field of terrestrial transport and multimodal domains, past activities exhibited a number of limitations in the way location technologies were addressed by various standardisation bodies (e.g. inconsistent GNSS-related requirements from one group to the other, or sub-optimal requirements resulting from possible lack of GNSS expertise in some groups). This was mainly the result of application-focused standardisation, regardless of the available location technologies.

Considering the service provision to an end-user or an external entity, the role of the location system is to provide consolidated information based on the position of one or multiple mobile platforms. The complexity of the information reported depends on the type of targeted service. It can range from a simple position reporting in the case of a low end asset management, to the provision of a reliable information (e.g. authenticated and with a bounded uncertainty) on the mobile's trajectory for liability critical services, such as road charging, or safety critical applications like Vehicle to Vehicle (V2V) or Vehicle to Infrastructure (V2I) for Advanced Driver Assistance Systems (ADAS).

This wide spectrum of required technical features calls for a new and broader concept at location system level taking into account hybrid solutions in which the use of GNSS technologies is complemented by other sensors to improve the robustness and the performance of the location solution.

Several standards have been already generated by different dedicated bodies in order to support the GNSS market development across the various application domains mentioned above.

For instance, 3GPP Location Services (LCS) standards provide minimum performance requirements mainly for Assisted-GNSS in the frame of terrestrial telecommunications and OMA-LOC LPPe (LTE Positioning Protocol Extensions) defines a communication protocol supporting hybridised positioning.

In road domain, a number of activities has been performed on specific areas (e.g. clean and energy-efficient transport, road congestion, traffic management, road safety, security of commercial transport operations, urban mobility) but in a non-optimized coordination manner since the 1980s. Some issues still need to be addressed from a European perspective to avoid the emergence of a patchwork of non-interoperable ITS applications and services, namely: geographical

continuity, interoperability of services and systems and component standardisation.

Despite this range of existing standardization initiatives, there is still a lack of GNSS performance specification for a large number of terrestrial applications (e.g. electronic fee collection, fleet management, container tracking ...), including multi-modal applications (i.e. those involving various modes of transport among which pedestrian). Thus, OMA and 3GPP standards related to location services, although widely commended, suffer from a lack of certain technologies in terminals (e.g. performance specifications), since they only consider GNSS receivers and communications modems for location purposes. This lack is a threat which could lead to the development and use of sub-optimal GNSS-based systems and solutions.

### **Identified Standardization Needs**

As exhibited in the previous paragraph, the overall market landscape lacks an unified standard framework in support of development of location-based applications. Up to now, this lack tended to lead to a fragmented standards background, causing each market to adopt undesirable features of too many proprietary implementations. Furthermore, some niche markets, not benefiting from a dedicated and adapted standard, are bound to rely on technological enablers potentially not matching their specific needs.

The initiative described in this article aims precisely at producing such a unified background standard, which will offer the single solid basis acting as catalyst to develop user-oriented location-based applications. This could lead to a set of European Standards.

In addition, by providing a converged standard, all location business actors will benefit from a more important variety of solutions, components or functions available, all simultaneously compatible with this standard.

Finally, such standard would provide a technological dictionary made available for any standardization body willing to include GNSS-related location technology in their technical specifications.

### **Task Coordination**

The need to unify the different standardisation initiatives was identified few years ago. In this context, the European Commission has launched important complementary initiatives in the frame of the EC M/496 Mandate to European Standardisation Organisations (ESOs) – see [2]. Addressed to CEN, CENELEC and ETSI this mandate requires to prepare standards and specifications for the various elements identified in different Sectorial Dossiers elaborated during M/415 activities – see [3]. Among them a high priority is given

to “Sectorial dossiers” linked with the Galileo programme.

In close coordination, the ESOs are currently implementing this mandate in the field (among others) of GNSS for terrestrial applications:

- ETSI TC SES/SCN WG deals with extended terrestrial GNSS applications (road, rail, multimodal, personal LBS) from architecture and technical point of view to produce Technical Specifications related to architecture, Data Exchange Protocols, Minimum Performance and Tests.
- CEN/CENELEC TC 5 Space WG1 will performed complementary activities to the ones performed by ETSI TC SES/SCN. The CEN activities will focus on mass-market road applications.

The work carried out by ETSI TC SES/SCN targets indeed location-based applications related to different domains:

- Transport domain (road, rail) (e.g. guidance, fleet management, road charging);
- Multimodal domain (applicable to various means of transport);
- Agriculture domain (in particular for precision farming);
- Finance domain (time synchronisation of financial operations across the globe).

This long-term coordination, initiated some years ago, already allowed the conduction at ETSI level of a study item, which aimed at demonstrating both the feasibility and the relevancy of such enterprise. This led to a first round of industrial stakeholder participation and to the generation of an ETSI Technical Report (see [4]), which is one of the starting point of the initiative described here.

For the sake of consistency of the standard production, the standardisation activities performed by ETSI TC SES/SCN are performed in close cooperation with others standardisation groups, namely:

- CEN/CENELEC TC5 “Space” WG1;
- 3GPP RAN/GERAN and OMA-LOC: 3GPP and OMA representing the main market for Galileo receivers; The work sustained under ETSI TC-SES/SCN is considered as a federation of the various GNSS-related standardisation tasks already pursued in these groups, and with which consistency shall be ensured;
- TCs responsible for standardisation in Intelligent Transport System for road: CEN TC278/ISO TC 204 and ETSI TC ITS;
- ETSI TC TETRA producing TETRA (Terrestrial Truncated Radio) standards, including A-GNSS.

### Structure of the Article

The next part of the paper describes the technical stakes of the standard production. It identifies then the four main tasks necessary to build the standard and the way they are

formalized within ETSI (Technical Specifications). The current status of the activities is addressed. Finally, the next steps of the standard production are presented.

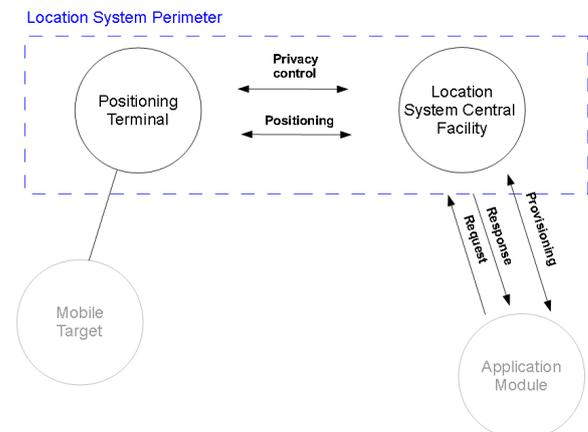
### TECHNICAL FRAMEWORK: MULTI-SENSOR TECHNOLOGY

A wide variety of location-based services exists among the market: road charging, goods or dangerous cargoes tracking, emergency calls, fleet management, precision farming, route guidance, etc...

In the frame of the on-going initiative, the most federating angle of attack is to consider that these applications are based on the processing of the location of one or more mobile targets.

Typical architecture of systems implementing these services is composed on one hand of an application module, in charge of interfacing with the user, and on the other hand of a location system (or sub-system) in charge of reporting to the application module some navigation information (mainly position and speed) related to the mobile target.

The diagram below illustrates the logical architecture addressed.

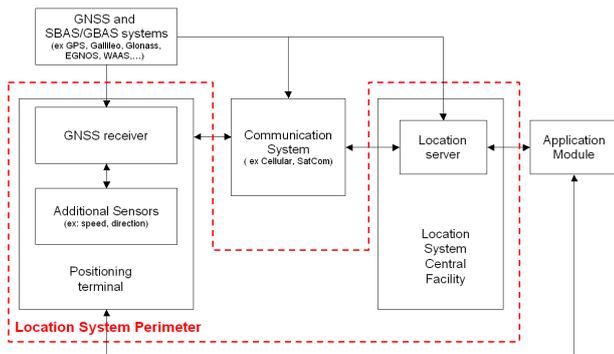


**Figure 1: Logical Reference Architecture**

The focus of the work undertaken is the location system itself, delimited in the figure above by the dotted line.

It is highlighted here that such system is responsible for provisioning navigation information related to the mobile targets. Its external interface towards the application module therefore only contains location-related information. The elaboration of further complex information downhill the processing chain (such as billing information for charging application, trajectory alarms for fleet management, or fuel consumption reduction strategy for precision farming) is left up to the application module, out of the scope of the work.

Location system structure typically combines GNSS (e.g. Galileo) and other navigation technologies, in charge of building the location information, with telecommunication networks, in charge of establishing a communication channel, as shown in the diagram below.



**Figure 2: Location System Perimeter**

The above macroscopic overview of the technical context enables to draw the main drivers of the needed work.

First, the standard under construction shall propose a unified vision of the location system architecture. The vision shared here envisions two main sub-components:

- the positioning terminal, dedicated to be co-localized with the mobile target mentioned above; this terminal is equipped with all relevant sensors, and hybridization modules.
- the system “central facility”, optional according to the type of application, and in charge of managing potential fleet of terminals, and implement to a certain extent some departed target localization function.

This architecture is compatible with the existing ones, in particular the widely spread 3GPP reference architecture (see [5]), but, thanks to its modularity, can also be adapted to other domains such as transport or fleet management.

It is highlighted here that the scope of work explicitly aims at covering multi-sensor positioning technology. Measurement hybridization, whether it is conducted in the positioning terminal or in the system central facility, is indeed considered as a key characteristic of the systems to be standardized. It is indeed the only way to reach the level of performance required by complex location systems in order to satisfy the expansion of location-based applications in the mass-market

As a result, the definition of a location systems generic architecture, down to the level of sensors and algorithmic modules, and their associated interfaces, is one of the cornerstones of the work undertaken.

Secondly, associated to this reference architecture, a set of minimum performance requirements applicable to the location systems shall be established. Based on the architectural choice made by the system manufacturer, various levels of performance will be achievable: a terminal composed of single GNSS receiver might probably be less robust than a multi-sensor terminal offering inertial hybridization.

The determination of the performance level function of the selected architecture will allow the provision to external stakeholders of valuable information:

- to application developers and standardization bodies with no navigation background, it provides discriminating elements for the selection of viable location system architecture.
- to manufacturers, it provides performance level targets to comply with a standard which is expected to be widely adopted.

Third, in order to complete the set of minimum performance requirements, test procedures need to be defined, in order to measure the system performance metrics for selected architecture options and the associated operational conditions.

Finally, once the system architecture, interfaces and performances are defined and the associated test procedures are established, a last fold of the activity consists in defining the location information data that shall be exchanged with the application module.

At the end, following these guidelines, the generated standard will offer a complete set of references available to most of the location-based services business actors:

- allowing to foster exchanges between domains, improving variety, quality and interoperability of technical solutions,
- supporting location-based application development in reaching a higher level of service,
- and offering the navigation expertise to external standardization bodies .

## TECHNICAL SPECIFICATIONS

In accordance with the above description of the technical stakes, 4 separate tasks, captured in the ETSI formalism under 4 separate Work Items, are identified.

It is highlighted that the execution of these tasks was initiated under ETSI study item leading to the publication of a Technical Report [4], in the previous phase of the initiative. These tasks, as they are presented and carried out here, have been determined after this first round of feasibility analysis.

**Task number 1<sup>3</sup>** deals with the generation of Technical Specification defining the Minimum Performance Requirements applicable to Location Systems.

As a preliminary work, the performances subject to specification, and the way to measure them, shall be clarified. In the frame of this initiative, previous analysis concluded on the selection of limited number of performance, called “performance features”, associated to their metrics. For instance, accuracy, the main performance feature, can be measured as Root Mean Square (RMS) of the horizontal position error.

<sup>3</sup> Under ETSI Work Item DTS/SES-00332 “Satellite Earth Stations and Systems (SES) - GNSS based location systems minimum performance” (adopted on 18.06.2012).

Further on, specific care shall be brought on the scenarios associated to the specification:

- Not only the type of the positioning terminal (and the range of sensors it is equipped with),
- But also any additional algorithmic layer (either at terminal or central facility level),
- And finally the type of environment and use case in which the system is used.

The challenge for this activity is clearly to accommodate this important number of degrees of freedom, and issue minimum performance requirements for a representative set of combinations.

**Task number 2<sup>4</sup>** covers the definition of the generic reference architecture, whose macroscopic view is given in Figure 2 above, and which has already been submitted to a 1<sup>st</sup> round of consolidation as reflected in [4].

The definition shall be completed:

- Based on a review of state of the art techniques, in particular regarding any new type of sensors considered relevant for the undertaken task and which shall be added in the reference architecture.
- The reference architecture shall also be defined so that it allows a modular implementation. Thus, although the reference architecture is composed of an exhaustive list of modules, it will be possible to define additional types of architectures, selecting a subset of these modules (e.g. type “GNSS stand alone”, or “GNSS + inertial”). It will then be possible to identify from the reference architecture which modules are applicable to a given domain. Thus several classes of systems will be defined, all “children” of the same reference architecture.
- Finally, this modular implementation ensures that, as new technologies or sensors arise (for instance from new user needs), the reference architecture can be extended to embed these new equipments.

**Task number 3<sup>5</sup>** addresses the definition of the location data exchange protocols between the positioning terminal and the location system central facility, and analyses the interactions between the location system and 3<sup>rd</sup> party application providers (application module in Figure 2). This aspect has indeed only been briefly tackled in the preparatory work leading to the redaction of the ETSI Technical Report [4].

The objective is:

- to carry out an analysis of the existing data exchange protocols among the various standardisation bodies, in order to assess their suitability to present framework. In particular, OMA LOC protocols will be looked at (see [6]).
- according to the outputs of the analysis either to identify and trigger the extensions of the existing

protocols to the present framework, or to build a new specification – consistent with the existing ones.

The data planned to be covered in this TS concern mainly the assistance data exchanged between the terminal and “location” server (A-GNSS, DGNSS, RTK, etc.), the location information reported by the terminal, and the handling of location report requests all through the system.

**Task number 4<sup>6</sup>** covers the generation of the test procedures to measure the system performance metrics for selected architecture options and the associated operational conditions. This allows providing an “end to end” standard.

The definition of the performance testing methods and procedures is associated to a number of challenges:

- A first problem to be solved is to build a test specification allowing the release of a clear procedure in order to test the various performance features output from task 2, which suffers from an important number of degrees of freedom.

This requires a clever solution, which allows to produce an appealing specification (i.e. limiting the number of test procedures, synthesizing at most the tests), but which would still allow the compatibility with the defined minimum performance standard (i.e. with the adequate level of coverage).

- The second challenge is related to the simulation of the test conditions and scenarios. The following trade-off shall then be considered :
  - o Basic environment models are easy to reproduce in test and the performances easily predictable, but with little representativeness of actual “real life” environments (typical example: Multipath model envisioning 1 single indirect beam).
  - o Real environments definition will be much closer to what the terminal will face in operational deployment conditions, but they come with important problem in terms of reproducibility, performance prediction and proper definition to be included in a test specification.

## CURRENT STATUS

The activities related to Task 3 (Technical Specification Data Exchange Protocol) and Task 4 (Technical Specification Test Procedures) have not started yet.

The activities related to Task 1 (Technical Specification Minimum Performance Requirements) and Task 2 (Technical Specification Architecture) have started. They are led in parallel following to the methodology described below.

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<sup>4</sup> Under ETSI Work Item DTS/SES-00331 “Earth Stations and Systems (SES) - GNSS based location systems reference architecture” (adopted on 18.06.2012).

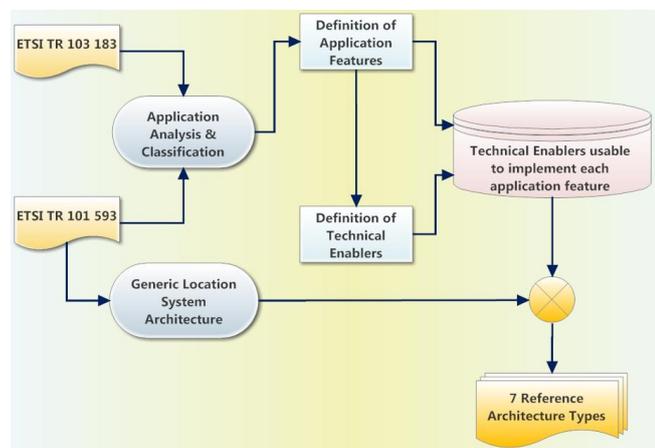
<sup>5</sup> Under ETSI Work Item “DTS/SES-00348, Satellite Earth Stations and Systems (SES) - GNSS based location systems; Requirements for the location data exchange protocols” (adopted on 13.06.2013).

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<sup>6</sup> Under ETSI Work Item DTS/SES-00349 “Satellite Earth Stations and Systems (SES) - GNSS based location systems - Test specification for system performance metrics” (adopted on 13.06.2013).

The methodology aims at providing a limited number of reference architecture types for GNSS-based location systems, to serve as common basis for the elaboration of the 4 Technical Specifications to be issued. The different steps, presented on Figure 3, are:

- **Application analysis and classification:** refinement of application classes based on the Technical Report ETSI TR 101 593<sup>7</sup> and ETSI TR 103 183<sup>8</sup>, issued by the TC-SES/SCN. The applications are function of location systems which include terminal types and central facility.
- The analysis of the applications covered by the standard is the starting point of **the definition of operational environments** to be used in order to specify and test the system performances.
- **Definition of application features:** identification and description of key features relevant to the application classes. Each application class is described relatively to a set of key features.
- **Definition of technical enablers:** identification and selection of the available technical enablers allowing the technical implementation of the identified key features.
- The last step consists in crossing application features and technical enablers in order to derive **location system architecture types**.



**Figure 3: Main steps for the definition of reference architectures**

Some progress has already been achieved in the definition of the standard, following the described methodology. The results are presented in the next sections.

### Application Analysis and Classification

The first step led to the inventory of the applications, which could benefit from location systems designed under

<sup>7</sup> Available on ETSI website at: [www.etsi.org/deliver/etsi\\_tr/101500\\_101599/101593/01.01.01\\_60/tr\\_101593v010101p.pdf](http://www.etsi.org/deliver/etsi_tr/101500_101599/101593/01.01.01_60/tr_101593v010101p.pdf)

<sup>8</sup> Available on ETSI website at: [http://www.etsi.org/deliver/etsi\\_tr/103100\\_103199/103183/01.01.01\\_60/tr\\_103183v010101p.pdf](http://www.etsi.org/deliver/etsi_tr/103100_103199/103183/01.01.01_60/tr_103183v010101p.pdf)

the guidelines fixed by the standard under development. These applications were gathered in seven classes (see Tableau 1), function of the key functions requested to the location system. This classification is provided in the following table, together with some examples.

Application classes	Examples
Location based charging	Road user charging
	On street parking billing
PAYD charging	Pay per use insurance
	Inland waterway charges
Cooperative basic geo-localization reporting	Transport on demand
	Road & Traffic data collection (V2V & V2I technologies)
Non-cooperative geo-localization reporting	Recovery after theft
	Fleet management
Reliable geo-localization	E-Call
Reliable vehicle movement sensing	Legal speed enforcement
	Eco-driving and Carbon Emission foot printing
Distributed system time synchronization	Telco Ground Infrastructure synchronization

**Tableau 1: Application classes**

### Definition of Application Key Features

Key functions associated to each class are listed here below:

- Reliability of the detection of virtual gates crossing (location based charging)
- The billing service unavailability (location based charging)
- Representativity of the computed distance (PAYD)
- Representativity of the reported trajectory (PAYD)
- Reported position accuracy (cooperative and non-cooperative geo-localization, reliable geo-localization)
- Location service availability (cooperative and non-cooperative geo-localization, reliable geo-localization)
- Service reliability, including spoofing attempts detection (non-cooperative geo-localization)
- Confidence level associated to the reported parameter (reliable geo-localization, reliable vehicle movement sensing)
- Movement caption accuracy (vehicle movement sensing)

Based on this classification, a list of technical key performance features has been built. This list is intended to cover the needs collected through the range of application listed above. Note however that, to that stage of the standard construction, it is not intended to provide an exhaustive list of potential location system performance features. The main objective is to limit the technical perimeter to an area which surely offers a relevant and exploitable standard for a reasonable set of stakeholders, but allows the standard publication within the near future.

The list of key performances intended to be addressed is provided below.

- **Horizontal accuracy** which is measured as the error between the mobile target position reported by the system, and its actual position. Horizontal accuracy is the derived 2D position error.
- **Availability of required accuracy** which is the probability that the system meet the accuracy requirement on a given period.
- **Time To First Fix** which is the time elapsed from power ON of the positioning terminal, to the availability of a first position estimate compliant with the required accuracy.
- **GNSS sensitivity** which is the ability of the system to report the terminal position when only low GNSS signal power is available (typical “in-door” use case).
- **Position authentication with Open GNSS signal.** This feature consists in being able to determine if the mobile target position reported by the system has been computed through a standard use of the positioning system of interest. The objective is to detect user of 3<sup>rd</sup> party frauds. Such feature has been thoroughly described in [7].
- **Position integrity** – protection level and Time To Alarm (TTA). This feature, usual in civil aviation domain, allows the association of a confidence level to the reported position, for the sake of the applications seeking for reliability. This is expressed as a protection level – PL, which shall be exceeded

only in low-probability cases, leading systematically to an alarm.

- **Robustness to interference**, which can be implemented either through beam-forming antenna, or more simple electro-magnetic interference blanking (time or frequency).
- **Interference localisation.** Such feature is proposed for applications where interference sources are not only part of the environment, but also part of the application purpose. This is in particular the case the military applications, or any location systems operating under potential harmful intentional jamming conditions.
- **GNSS denied survival**, which aims at testing system (and terminal) ability to put in place appropriate hybridization in order to cope with momentary cut in GNSS signals (covered areas use cases).

### Definition of Technical Enablers and Location System Architecture Types

Further to the performance inventory, reference architecture has been devised, with the objective to account for a set of technical enablers which will allow the implementation of the features above. Once again, the modular architecture proposed might not be exhaustive in terms sensors, but offers the possibility to be updated along the standard lifecycle.

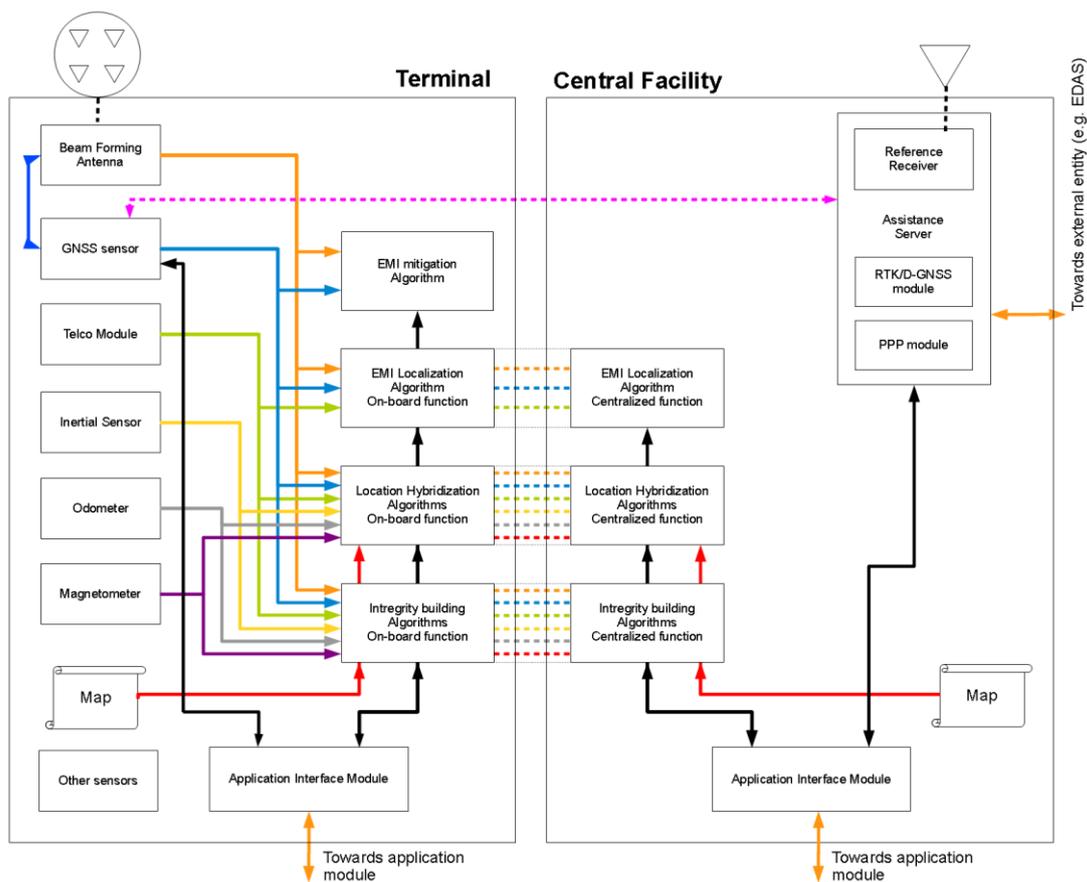


Figure 4: Location systems architecture

As mentioned in the introductory sections, the selected generic architecture envisions a number of additional sensors able to provide measurements to the navigation solution through hybridization algorithms.

Among these sensors:

- **Telecommunication module** is the generic entity through which the positioning terminal can connect to the system central facility. It is not only used to open the communication channel conveying all location-related information (assistance data, location requests and reports, or measurements repatriation), but is also used to provide additional location-related measurements to the hybridization layer (e.g. in the 3GPP framework, handsets GSM modem is able to provide cell-ID information or further elaborated measurement, such as OTDOA measures).
- The possibility to embed a **beam forming antenna** is also considered in the generic architecture, enabling improved interference mitigation functions on-board the terminal. For architecture not envisioning such device (i.e. in most cases), a regular passive omnidirectional antenna is considered.
- **Map** is also listed in among the technical enablers due to the need to take on-board map-matching techniques (hybridization of measurements coming from GNSS sensor (or other), and information collected from the geographical map, with the objective to refine the position estimate).
- **An assistance server** is also proposed to be considered – located in the system central facility. This server is not only in charge of implementing the usual functions of assistance server (such as SMLC/SPC in 3GPP/OMA frameworks) but also provides services related to RTK, DGNSS or PPP.
- A set of **algorithmic modules** are also considered, each one dedicated to implementation of a specific feature: **EMI mitigation algorithm** processes data from GNSS sensor and beam forming antenna, in order to implement mitigation techniques. Note that if this module can be functionally dissociated, it is more often physically merged to the GNSS sensor itself. Additional algorithmic modules related to **interference localization**, **measurement hybridization** and **integrity determination** are also considered, all processing data coming from the various sensors available on the terminal. Note that these functions can be implemented on-board the terminal itself (“on-board function”), or at the central facility (“centralized function”), in which case sensor measurements need to be repatriated through the telecommunication network.

As exposed previously, this generic architecture is proposed as a basis allowing the construction of typical architectures, adapted to various domains, selecting a subset of relevant sensors and modules. Thus, a limited

number of seven typical architectures has been considered in the scope of the first release of the standard under development:

- Multi-constellation stand-alone GNSS terminal,
- Road Tolling / PAYD On-board unit / Railway Location Units,
- 3GPP, including assisted GNSS, and use of NW assets for ranging information,
- Autonomous Personal Navigation, including car on-board receiver,
- High precision positioning (farming), including D-GNSS and RTK,
- TETRA + GNSS module,
- Personal Navigation Device (TomTom-like).

The examples of possible road tolling and 3GPP location system architectures are proposed below.

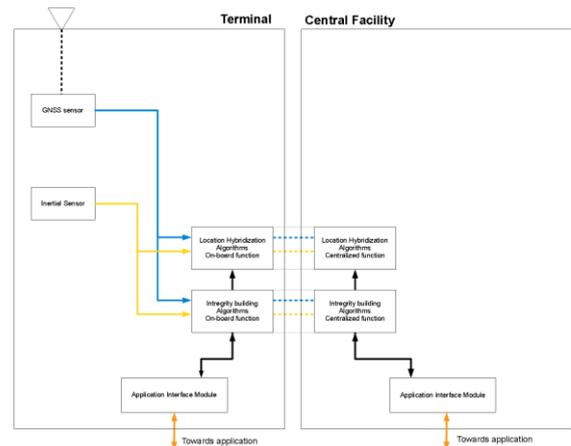


Figure 5: Architecture type “Road Tolling Units”

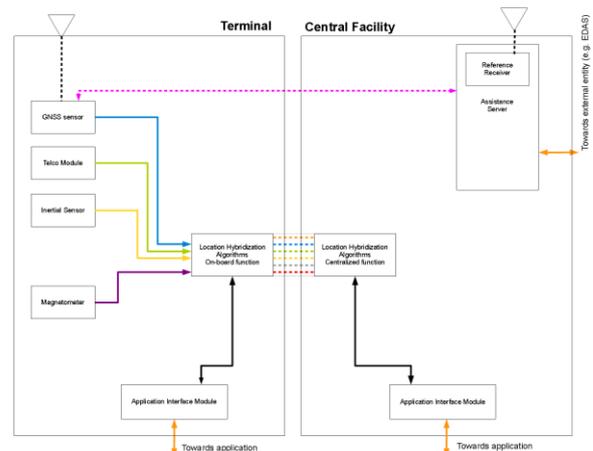


Figure 6: Architecture type 3GPP

### Definition of the Operational Environments

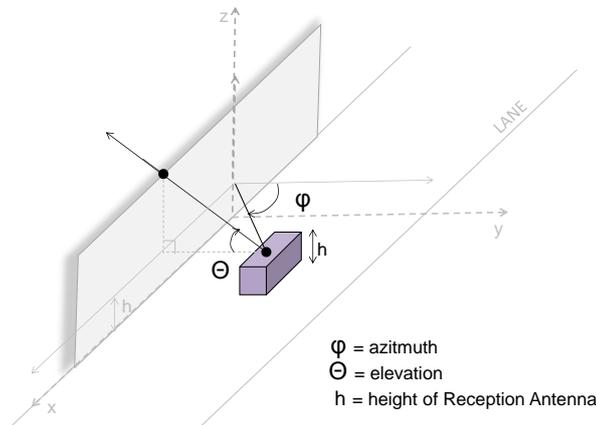
Finally, in addition to the performance feature selection and reference architecture identification, significant activity has been executed on the definition of the

operational environments to be used in order to specify and test the system performances.

Thus, the objectives are to determine a set of environment characteristics driving the performance features, to choose a model for each of these characteristics, and to tune these models in order to make them representative of the various operational environments applicable to the scope of the undertaken work .

The results shall be a list of “typical” environments, each of them associated to a given tuning of the physical model. To that stage of the activities, the models considered relevant to sufficiently characterize the environment are the following ones:

- **Elevation Mask:** the elevation mask corresponds to the angle between the horizontal at receiver antenna level and the direct line of sight just beyond the obstacle height. The GNSS receiver does not receive the direct line-of-sight signals of satellites located below the elevation mask, which are obstructed by the obstacle. The elevation mask can vary with the angle of azimuth (mainly along and across the lane).



**Figure 7: Elevation Mask**

- **Signal Attenuation:** Signal attenuation refers to any decrease of GNSS signal power at the level of reception antenna. The attenuation, expressed in decibel (dB), corresponds to the rate between the power of GNSS signal at receiver antenna level and the nominal GNSS signal power - at the emission.
- **Multipath:** Signal arrival at a receiver antenna by way of two or more different paths such as a direct line-of-sight path and one that includes reflections off nearby objects. The difference in path lengths causes the signals to interfere at the antenna and can corrupt the receiver's pseudorange and carrier-phase measurements.
- **Interference:** Interference denotes emission of signals in bands close to GNSS's, which are disturbing GNSS signals. These emissions can be transmitted unintentionally or intentionally.
- **User dynamic:** User dynamic corresponds to the dynamic of the mobile target and represents its

attitude. It is characterized by the velocity, acceleration and jerk of the terminal.

The tuning of the models selected for each of these characteristics is under process. The objective is to simulate the following typical operational environments:

- **Open** area: user is in open area with clear sky view, with not constraining multipath and interference conditions.
- **Rural** area: characterized by the presence of dense vegetation.
- **Suburban** area: characterized by small blocking structures, buildings or natural geographical obstacles (low risk of multipath and interference).
- **Urban** area: characterized by high rise structures, buildings or natural geographical obstacles. It also corresponds to a densely constructed area. The risk of multipath is high.
- **Covered** area: GNSS-denied environment, such as indoor conditions, tunnels, stations or bridges.
- **Industrial** area: characterized by the presence of metallic structures, radio sources, cables, overhead lines, gantries, catenaries, intentional or un-intentional jammer. The number of multipath and the related error are high.

Note that in parallel of this baseline environment characterization, an alternate approach has also been investigated. This approach aims at simulating environment conditions closer to actual the real life conditions.

Within such approach, the use of RF replay techniques has been considered. To that day, and based on an inventory of the use of these techniques among the community, it has not been considered relevant to take them on-board the standardization action plan; however, this option is left open, and it is considered acceptable that, within a next release of the standard, these new techniques are introduced in order to issue minimum performance requirements and associated testing procedures.

## NEXT STEPS

The targeted GNSS-based Location system standard will be composed of four Technical Specifications:

- TS “Location System Reference Architecture”.
- TS “Data Exchange Protocol”.
- TS “Location System Minimum Performances”
- TS “Test Specification, Procedure, Scenario and Data”.

The issue of the TSs “Location System Reference Architecture” and “Location System Minimum Performances” is expected in December 2014, after their approval at Technical Body level (i.e. ETSI TC-SES).

As far as the architecture related TS is concerned, the reference generic architecture being well defined, the next

step is to describe the interfaces inside this architecture. To define standardized interfaces for key modules, such as GNSS sensors or inertial sensor, is indeed one of the expected major added values of the standard.

Regarding minimum performance requirement TS, once the operational environment tuning is executed, most of the activity will consist in executing simulation and real-life trial in order to determine achievable performances for the various system architectures considered.

In parallel the activities related to the development of the TSs “Data Exchange Protocol” and “Test Specification, Procedure, Scenario and Data” will start. These TSs are expected to be ready by April 2015 (idem, after TC-SES approval).

## CONCLUSION

Once realized, the undertaken initiative to elaborate an unified standard for GNSS-based Location systems will benefit to various stakeholders at all levels and act as an enabler to take up the next generation EU challenges.

First, it will act as catalyst to develop user-oriented location-based applications.

Then, all location business actors will benefit from a more important variety of available solutions, components or functions, all simultaneously compatible with this standard.

Such standard will also provide a technological dictionary made available for any standardization body willing to include GNSS-related location technology in their technical specifications.

Finally, this converged standard will fit the current EU policy needs and could play an important role in the creation of a European Mobility Network by enabling the deployment of pan-European applications – synonym of the creation of job and wealth in Europe.

Standardization still remains a long and complex process, but all conditions are there to ensure the successful completion of this initiative. The first publication of the GNSS-based Location systems standard is expected in April 2015 and first results are already visible today.

## ACKNOWLEDGMENTS

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