

Mobile Telematic Applications Based on Object Positioning

Kornel B. Wydro

Abstract—Global positioning systems makes possible to build a new telematic systems, enabling various applications and services in many branches of economy. A special area of such applications are various transport and transport related tasks. Among them, of a high importance are applications applied to mobile objects, for example, to all kinds of vehicles, called mobile telematic services. The paper presents features of such a services, with a special emphasis of the services being foreseen in Galileo satellite positioning system. Even conditions concerning such a service constructions are discussed, having in mind mainly necessity of complementary communications between a positioned object and related surrounding, including co-users of the movement area infrastructure as well as broader environment.

Keywords—Galileo, GPS, intelligent transport, telematics.

1. Introduction

The positioning systems, enabling object geographical positioning or localization, find – especially relatively to vehicles – more and more broad applications and use for, among others, their common and cost-free accessibility and also for progressive drop of equipment prices. But beside of popular among drivers global positioning system (GPS) navigation services, there is possibility to apply the positioning services to other needs, for example, to support some automatic control solutions, mainly related to the production processes with moving bigger physical elements in more broad spaces, e.g., mobile robots. Obviously, in such a case requirements imposed on positioning accuracy, reliability and accessibility are to be much more stronger as in nonprofessional form of GPS navigation. Yet here, for more concrete illustration of the possibilities, the problem will be discussed mainly in relation to transport applications.

Positioning systems are mostly satellite supported ones, but in last time are even developed on the basis of the mobile telecommunications networks, mainly cellular ones. But is to be pointed, that satellite systems are build intentionally as positioning systems, while cellular systems offer such a possibilities thanks for their immanent manner of terminals connecting to the transmission network through the changed base stations during the move of the terminal.

A most important and known satellite systems are the global positioning system build by US mainly for military applications, but with reduced precision available for global civil usage, and Russian system called in Russian “*globalnaja nawigacjonnaja satielitarnaja sistiema*” (GLONASS).

In the professional (precise) service option GPS allows to locate objects with accuracy of ca. 3 m, in standard one – from 100 to 50 m, dependently on local circumstances. The GLONASS in standard service option allows to locate horizontally with precision to 60 m, and vertically – to 75 m.

Portable cellular terminals in some favourable conditions, even are to be localized with accuracy of few meters, but as it is not intentional function of their applications and networks, possibility of use and reliability of such a positioning is strongly limited, therefore cannot be used as a basis for building some service systems. It comes from fact that positioning in such a case needs in principle the overlay signal fields from more than one base station, what in normal circumstances occurs not so often. Even for increasing such a possibility, should base stations emission be stronger, what is rather unfavourable for natural aims of the mobile network.

Having in mind not a satisfying actually possibilities, conditions and circumstances of GPS services use as well as expectations for more advanced services, EU during last years undertaken building an own, more modern positioning system named Galileo [1]. The system will offer to all the interested stakeholders positioning services with a high guaranteed reliability. It will create profitable circumstances for improved activities of the persons, enterprises and administration entities related to various processes with mobility factor and position detection for all the objects – if provided with proper receiver – in their interest area.

2. Basic Galileo Services

Following categories of services are foreseen in Galileo system [2]:

- **Open services (OS)**, enabling unconstrained free access to signals combination delivering object geographic position and time data.
- **Safety of life services (SoL)**, being improved version of open services enabling warnings to users coming nearer to some serious danger places or situations.
- **Commercial services (CS)**, providing accessibility to two additional signals allowing higher transmission capacity and better positioning accuracy with guaranteed quality and also additional transmission band for information broadcasting from centres to users (500 bit/s).

- **Public regulated services (PRS)**, giving positioning and time signals for users requiring continuous services with controlled access. Here two adequately coded navigation signals will be delivered.
- **Search and rescue services (SAR)**, delivering broadcasted in global scale alert signals coming from systems detecting catastrophic situations and supporting systems of search and rescue COSPAS-SARSAT.

More detailed expected technical characteristics of the basic Galileo services are presented in Table 1.

Table 1
Some technical parameters of Galileo positioning services [3]

Parameters	OS	SoL	CS	PRS
Accuracy	H:15 m	–	–	–
OFR	V:35 m	–	–	–
Accuracy	H:4 m	H:4 m	0.1–10 m	H:6.5 m
TFR	V:8 m	V:8 m		V:12 m
Timing accuracy	30 ns			100 ns
Integrity	No	Yes	Yes	Yes
Alert limit	–	12–20 m	2–45 m	3–15 m
Time to alert	–	6 s	1–10 s	1–6 s
Certification	No	Yes	Possible	Yes
Serv. guarant.	No	Yes	Possible	Possible
Explanations: OFR – one frequency receiver, TFR – two frequency receiver.				

It has to be added, that some more precise services (for the positioning with accuracy better than 4 m) are to be achieved with help of local augmentation signals¹.

The accessibility of the all the Galileo signals are estimated in the level of 99.5–99.8%, accuracy – as 95% and risk of credibility (for SoL and PRS) in the range of $3.5 \cdot 10^{-7}/150$ s. Such values of parameters are to be achieved thanks for applied broader transmission bands enabling higher accuracy and stronger signals as it is in GPS or GLONASS. In result, it will make possible to use satellite navigation even in buildings and tunnels.

Defined above the “pure” Galileo services can be improved by its combination with other ground located completing technical means, enabling design and implementation of the more advanced or specially profiled applications. In such cases particularly important is proper and extended use of the local electronic communication means, ensuring information transmission between localized object(s) and surrounding elements or entities, being in the area of interest of singular user, pair communicating one to other or multilateral communication. Obviously, in such cases systems

¹ Generic Galileo signals will be transmitted in radio-navigation satellite service (RNSS) band, i.e., 1.164–1.215 GHz (signals E5a i E5b), 1.260–1.300 GHz (E6) and 1.559–1.592 GHz (E2-L1-E1). It is possible even usage of C band (5 GHz).

of mobile communication will play an especially important role. Altogether, it shows that Galileo positioning system can be advantageous even in constructions of, e.g., control systems for various production and building processes². It seems to be particularly applicable to big, geographically wide control systems with moving elements, like, e.g., floating car data collection systems (FCD) or automatic farming operations (precision or “intelligent” farming, i.e., targeted crop and fertilizer dosing).

In this context is to be pointed, that from the service systems using localization data point of view, a very important ground element of the Galileo system is mission control system (MCS). There will be a network of 20 MCS stations whose will execute tasks of maintenance of basic services provided by Galileo, monitoring of the systems operation, analyzing signals emitted by system’s satellites and spreaded transmitted data. In MCS, beside of blocks such as orbit synchronization and processing facility (OSPF), integrity processing facilities (IPF), satellite control facility (SCF) and message generation facility (MGF) in which will be created navigation telegrams, will be installed very important for building service systems blocks of precision timing facilities (PFT) and services product facility (SPF).

3. Foreseen Applications of the Galileo System

The constructors of the Galileo system expects, that on the basis of its services will be created numerous telematic service systems and applications which, from one side, generally will contribute to economic development of particular countries, to building of the new places of labour, to extend technical development and from other allow to implement solutions and applications which will enable at least partial revenue of the investments on system’s building. Those expectations are more precisely specified in form of the main areas of Galileo service applications, as listed below [3].

- **Location** – positioning services with high reliability and precision for individual persons and various objects as well mobile as motionless.
- **Rescue** – systems of guidance specially adopted for firefighters, ambulances, police and other, ensuring faster rescue actions. One expects to achieve a higher efficiency of those actions, more secure transport, lessening of accidents leading to the disabilities or fatalities.
- **Guidance** – guidance assistance for the impaired, mainly blind.
- **Entrepreneurs support** – aid to all the economies branches, like agriculture, forest and water economies as, i.e., fishing, assistance in natural resources prospecting and exploitation.

² Obviously, rather as PRS and CS services.

- **Management support** – assistance for actions in favour of environment protection, atmosphere monitoring, wild animals monitoring. Also assistance for such activities as public transport.
- **Study and research support** – research of natural environment, seismic and volcanoes activity. Providing exact time signals for telecommunications, energy transmission, banking and other.

An important part of the Galileo system will be the accompanying special user segments. Their task is defined as positioning system's exploitation as a basis for creation various forms of original Galileo services usage. Keeping in the mind that a main area of the expected services is seen transport branch, where positioning – combined with use of the proper geographic information systems (GIS) – stands for one of the most important elements which enables improving realization of the various ventures undertaken in this field, below are given some related comments, bringing closer arising problems.

To main domains having advantage of satellite positioning systems, essential in the surface transport as well as in aerial and water ones, belongs:

- monitoring of the transport entities, especially carrying passengers or hazardous materials;
- management and control of the vehicles and especially streams of those;
- supporting individual drivers of transport means;
- expanding security level in all the transport modes, especially in catastrophic or breakdowns cases.

A monitoring tasks are in this case of crucial importance, as those should allow collecting all the necessary information on systems and surrounding states and circumstances [4]. In order of providing an efficient tools in monitoring area for realization above listed tasks, it's necessary to undertake building and development of intelligent monitoring systems which will be equipped with proper algorithms for identification of – first of all – breakdown situations and will enable, for potential operators or other service teams, unambiguously detect other difficult circumstances requiring quick intervention, as well as support decisions making for, e.g., the accidents management.

In the traffic streams management and control, occurs a need of introduction of new solutions making use of the Galileo system's services. Those should be constructed with possibility of unaided defining the optimal procedures of management of traffic parameters and, by the remote control means, reducing jams and congestions. Is to be underlined, that it may effectively increase transport efficiency by reduction of losses arising from, e.g., stoppages and in this way contribute to economic advantages.

Very important possibilities are offered by new methods of drivers support with positioning data. As a driver (or vehicle) can be equipped with digital maps, data basis describing elements of the environment and algorithms enabling

delivering to drivers or operators only those information, which are directly related to driving action just in given circumstances, efficiency and first of all – safety and security can be evidently improved. Such systems, completed with decision support computer aids algorithms and equipped with trajectories and routes optimization procedures for particular vehicles, considering at the same other traffic participants as well as actual circumstances and situations, will allow exchange among infrastructure's users the properly tailored information about actual traffic conditions.

What concerns more precisely the area of security, it can be pointed that Galileo constructors expects creation of enhanced systems, which thanks for precise and reliable positioning data, will enable quick realization of rescue actions, better their integration and coordination, preventing spreading of the catastrophes and reducing their results as well as enhancing of crisis management methods. Taking that into account, even important is a possibility of upgrading of existing accident's monitoring systems, aimed on stimulation or forcing of the regulations obeying and protection against various accidents and even a terrorist actions.

Other special areas of Galileo services usage are seen as follows:

- Management of energy transmission, where precise time tokens received from Galileo will enable current flows optimization and fast restoring of network after breakdowns.
- Finances, banking and insurances. In those areas the time tokens will enable integrity, authentication and safety of electronic transactions. Even continuous monitoring of the valuable or danger cargos during their transport, standard installations of suitable systems in cars enabling continuous monitoring, will be a crucial subsystems applied by insurance companies.
- Personal navigation. One estimates that it will be a domain with most broad spectrum of applications: starting from guidance support in unknown terrain and delivering actual information about it, by surveillance on disabled persons, children or workers of public services, especially during circumstances of danger, up to additional support for broadly understood recreation.
- Search and rescue. Receivers and transmitters detecting and passing on their position thanks to Galileo, will enable fast location of missing planes, vessels, vehicles and persons.
- Management in crisis situations like floods, earthquakes, forest fires. Management from command centres will be much easier thanks information received and transmitted through Galileo system.
- Crude and gas mining, environment management, agriculture and fishing – are other possible areas, where new possibilities and benefits are expected, when will be supported by Galileo services.

Listed above areas of the Galileo generic services usage suggests also a broad possibilities of applications in automatically working systems, yet under guarantees of high quality, reliability and continuous accessibility to the signals transmitted by Galileo, and consideration of the accuracy limitations.

As an example here can be called on a problem of autonomous navigation of a team of cooperating agents. The main objective in such case is the validation of localization, map building and motion planning algorithms allowing to construct a map of the surrounding environment and figure out the trajectory that each agent should follow in order to accomplish the desired tasks. To do it proper algorithms have to process the information provided by the various sensory system of each agent, e.g., range and bearing measurements coming from positioning satellite system, sonars, rangefinders, stereo cams, etc., consisting of relative absolute measurements related to static landmarks. Moreover, suitable dynamic models, accounting for the motion of each moving object, have to be considered.

4. Conditions for Building Systems Based on Galileo Services

As the Galileo signals have to be utilized for construction of the various services for transport and other applications for control of object movement, it is valuable to analyze conditions necessary for it, which have to be fulfilled. Those are of various kinds, mainly of technical, organizational and legal type [5]. All the kinds of conditions are of high meaning as the constructed applications can influence security of many peoples and valuable goods as it is in commonly used great transport system. A short discussion of those conditions is done below.

4.1. Technical Conditions

Making use of the geographical location data in the manner more complex than only informing driver about his position, is conditioned by accessibility to technical means enabling communication with environment being in his interest, especially situated on the co-used infrastructure and proper equipment belonging to it (e.g., signs systems). The thing is mainly concerning the auxiliary electronic communication equipment, first of all the mobile ones, making possible connections controlled by driver, as well as in automatic way. General structure of a system of communication between driver/vehicle and environment, firstly roadside equipment and mobile services providers, is shown in Fig. 1. Obviously, the proper related communication equipment is, or has to be, installed on and around the movement infrastructure.

The position and time data coming from satellite system are relayed to driver and to car-boarded automatic or/and "hand" controlled telematic call system to trigger of a proper mobile services. Those position and time pa-

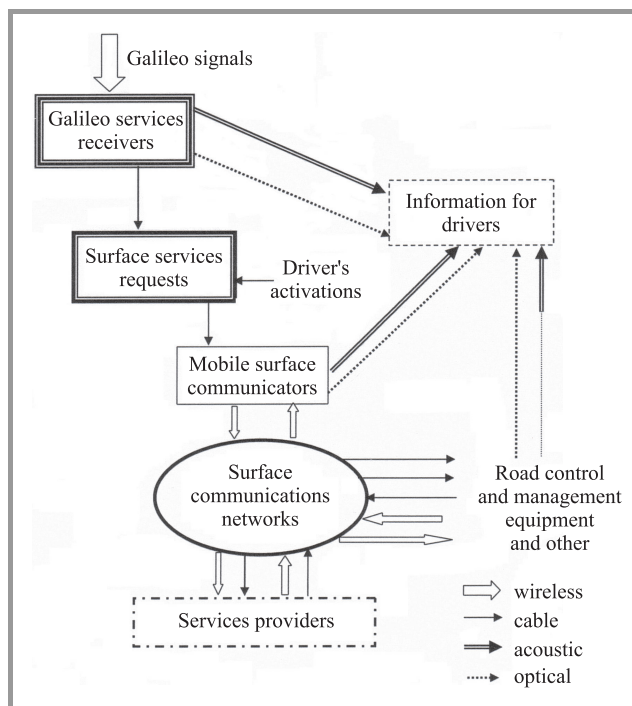


Fig. 1. Ground local communication means for positioned object.

rameters are to be identified – as foreseen by Galileo constructors – by range of various receivers suitable for various groups of mobile services recipients, dependently of their demands and used applications. There broad variety of receivers are planned to be build for more common use, but also a specialized receivers are foreseen for special user's segment.

The call signals will be relayed with the help of the mobile communication means to the communication network existing in surrounding. The Galileo signals receivers, as well as equipment for service's and other calls, like cellular terminals, in near future most probably will constitute standard on-board equipment.

The calls from moving object or vehicles are mostly send to the service providers and fulfilled by them with feedback information to caller in the form of a announcement or as activation signals to infrastructure's (road) information system. Obviously announcements for drivers should be preferably acoustic, but has to be even optic, as it has to reach the driver (or driving system) with highest probability. Anyway, operations on the communication means by a driver should in the minimal manner be fulfilled manually. Furthermore, all the cooperating systems have to be of high reliability ones.

In the area of dynamic development of the electronic communication systems an advice defining some specific kind of communication means are not proper (except their technical parameters, reliability and, may be prices). But of great importance is assuring of the information exchange in agreed formats, securing mutual articulated communication between all the system's elements. As a good basis for implementation of such communication manner can be

seen open communication interface for road traffic control systems (OCIT)³ structure [6].

Other important technical factor enabling effective usage of the possibilities given by Galileo services is to have proper data basis systems and its contents. To data basis contents have to be included all the digitalized information collected and provided for users with special regard to services for moving objects. There will be digital maps, data basis with informations concerning the infrastructure and surrounding description and so on. Beside data describing some durable, constant elements, there is very important to have information on elements and occurrences of the random, not planned situations. Detecting and communicating in proper manner such an incidents makes real difficulty from the technical and formal point of view (e.g., problem of credibility).

As main elements of the information system can be recognized digital maps, geographic information systems, supporting metering and sensing equipment and information centres (all using an electronic communication network).

Digital maps. Various digital maps stands for the basic graphic description of the geographic location of the moving object and it's movement trajectory. As the map data are recorded in digital form, there is possibility to use those data not only to demonstrate area being in interest of driving entity, but also make some additional operations, like situation analysis, e.g., how is far to some defined point. There are distinguished raster maps and vector maps. The raster ones have advantage of possibility to be operated by commonly accessible software, what enables making some actualizations and corrections. The vector maps however ones enables scalability without degradation of picture quality. The raster maps use to be completed with vector layer, what may help for example to find streets. Also are used a "scanned" maps, especially when some specific elements of the area is to be demonstrated.

Geographic information systems. Beside typical cartographic data included in digital maps, an important source of basic information for driving processes are various geographic information systems, based on data bases or warehouses describing some terrain objects, which content is combined with digital maps. Is to be emphasized that usually those data are describing mainly durable objects, mostly infrastructural ones. For this reason it is important to remember actualize the in cases of reconstructions, extensions or liquidations of infrastructural elements.

Metering, sensing and controlling equipment. For the enabling collection of the information necessary for driving operations and controlling devices (e.g., road signs), the moving infrastructure have to be equipped with proper set of detecting, metering and sensing elements relaying data to the interested entities, as well as movement regulating means [4]. Taking the road traffic management as an good illustrating example can be pointed that all the tra-

ditional systems are to be used as interacting with driver, but not automatic driving means. So it is necessary to add some completing equipment to enable fulfilling contemporary needs [7].

Actually, as the moving object sensors are applied:

- magnetic loops,
- pneumatic sensors,
- piezoelectric cables,
- video cameras,
- radars,
- infrared and other passive sensors,
- active radio- and landmarks,
- FCD networks basing on GSM/GPS technologies.

It is to underline, that for traffic measurements and identifications of the vehicles and drivers are more and more applied systems with image analysis coupled with the radars measuring vehicle's speed. Also some modern thermal technologies are applied to analysis of the road surface. However, for the traffic control goals are applied so called variable message signs (VMS).

For cooperation with those elements of the infrastructure are necessary proper communication methods and means, mostly of the short range reach (ca. few hundreds meters), but of high reliability and security, as they serves also for the payments realization. As such a means com-

Table 2
Some technical parameters of communication systems used in transport telematics

Communication system	Range	Bandwidth
DSRC	0.5 – 1 km	6 – 27 Mbit/s
GSM	ca. 35 km	9.6 – 57.6 kbit/s
GSM/GPRS	ca. 35 km	53.6 – 171.2 kbit/s
GSM/EDGE	ca. 35 km	296 kbit/s
GSM/HSDPA	ca. 35 km	1.8 Mbit/s max. 7.2 Mbit/s
GSM-R	ca. 35 km	2 × 4 MHz
3G (UMTS)	ca. 1 km	384 – 2 000 kbit/s m
WiMAX (IEEE 802.16)	10 km	ok. 2 Mbit/s max. 75 Mbit/s
Wi-Fi (IEEE 802.11)	50 m max. few hundr. m	10 kbit/s max. 108 Mbit/s
TETRA	ca. 10 km from BS	speech 2.4 – 7.2 kbit/s data 9.6 – 28.8 kbit/s
PSTN/xDSL	few km	784 – 2 300 kbit/s
DECT	250 m	9.6 – 57.6 kbit/s
Bluetooth	up to 10 m	to 1 Mbit/s
IrDA (infrared)	few hundr. m max. few km	1 – 500 Mbit/s

³ The standard is actually developed mostly by German-language countries: Germany, Switzerland and Austria.

monly are used systems known as (radio frequency identification – RFID, especially in dedicated short range communication – DSRC) technology or infrared links. Some approximated technical characteristics of communication systems used in transport telematics are presented in Table 2.

From other side, moving objects have to be equipped with relevant on-board communications means (in some cases even with automatically acting ones), constructed with a special consideration of a man-machine interactions rules. It is observed that temporary the on-board equipment is fitted to encompass needs arising from possibility of the realization of mainly following services:

- route selection and guidance,
- prevention against side and back-front collisions,
- signalization of the vehicle malfunctioning,
- automatic accident signalization,
- forcing the driving rules obeying,
- anti-thief protections,
- travellers comfort enhancement.

Many of such a solutions starts to be a standard or optional equipment of contemporary new, mass-produced cars.

Centers of temporary information. Obviously all the informatic structure supporting telematic systems and services, has some centres in which information is collected, analyzed, filtered and from which is distributed [8]. But of special attentions, as it was said earlier, are those, which operates on information regarding temporary, incidental and random situations being of particular meaning for the driving systems, especially automatic ones. By temporary situations are here understood such ones being planned for defined place, time and scope with some properly communicated prejudice (e.g., road works). As incidental or random ones have to be counted like as accidents, weather conditions changing and so on. Named two kinds of non-durable situations calls for special centres of collecting data, as information coming from high variety of sources needs careful analysis regarding credibility, integrity and value and special methods of diffusion. Obviously such a information is extremely valid for objects narrowing the places of incidents, but worthless for all others (except of those making statistical analysis)⁴.

4.2. Organizational Questions

Beside technical ones, there are numerous constrains of the organizational nature concerning building methods of the considered service systems, their technical basis, operation

⁴ In this respect interesting seems to be usage of the geotagging technique, i.e., possibility of adding on the cameras picture data describing geographical coordinates of the place in which the picture was made, as well as precise time.

and management, and among those, even legislative [9]. The main areas whose need extended feasibility studies and agreed implementations are:

- Financing of the building of mobile service's systems as ventures serving to broad public use at limited payments or fully free.
- Need of integration and agreement of system's building, development and management processes with the competitive infrastructure owners, operators and administrators.
- Ownership and owners rights to the systems and data collected and conitions of use of it.
- Arrangements on the cooperation between build systems and public services of rescue, security and assistance.
- Constrains coming from actual law regulations concerning the infrastructures and traffic, as for today not sufficiently considering technical development and possibilities [10].

Financing problems are probably the crucial factors very difficult to solve. By virtue of necessity to possess highly specialized design and building potential, an administration of the infrastructure will be forced to realize discussed solutions and management of them by the outsourcing methods. This calls to take into particular consideration question of finance sources, as private entrepreneurs will be not intending to invest some meaningful sums on investments at which they have consciousness that the return time can be especially long and recovering of dues may be complicated.

Other difficulties may arise in the area of law, mainly related to responsibility. It is obvious, that in the transport processes may occur also serious damages and fatalities. As the advanced telematic technologies can influence on the behaviour of infrastructure users – mainly very numerous and psychologically an physically differentiated users – the the serious question is the possibility of recognize how far the personal responsibility is constrained by eventual failure of telematic system as well as it concern accidents, as obligatory payments (electronic fee collection).

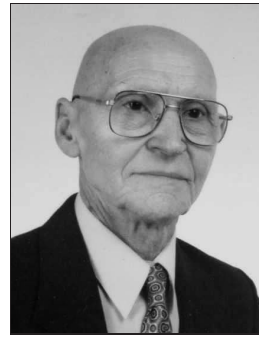
5. Final Remarks

Fulfilling all the expectations concerned with design, construction and exploitation of the new solutions using Galileo original system services should be a real interest of each individual or institutional user as well as of all – especially European countries – as the system is build with financing in great part from EU budget [11], [12]. In other side is to be considered, that all the phases of Galileo implementation – design, building, operation, enhancement and exploitation can bring real advantages a stimulating impacts on the economic and social processes in all the countries.

So contribution of particular countries and institutions in the area of financing, science works and entrepreneurship should be an interest of their own. But it has to be executed with deep knowledge concerning all the possible constrains and threats.

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