POSITIONING FOR NEXT GENERATION INTELLIGENT TRANSPORT SYSTEMS SERVICES IN SAFETRIP

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ABSTRACT

SafeTRIP is an integrated project of the European Union (total research effort: €11.5M) involving 20 partners from many European countries. Its primary goal is to efficiently exploit the S-band communication via W2A satellite to improve road safety and to provide state-of-the-art on-board communication solution for the transport stakeholders.

Besides the communication issues in Intelligent Transport Systems (ITS) services, positioning solutions are also analysed within the project. Each SafeTRIP on-board unit will include a GNSS receiver that is able to receive GPS, GLONASS and GALILEO signals. Solutions for improving accuracy and coverage will be investigated, i.e. applying SBAS and GBAS systems, satellite-based RTK solution, and – as a separate subsystem – GSM-based positioning. Budapest University of Technology and Economics (Hungary) and the PIAP Industrial Research for Automation and Measurements (Poland) are responsible for the analysis of the positioning and navigation system requirements and the positioning system architecture.

The paper discusses the architecture and the services that will be supported by the SafeTRIP platform, especially focusing on the positioning and navigation issues. The paper also includes the analysis of the potential of GSM-based positioning to support ITS services.

KEYWORDS: intelligent transport systems, positioning solutions, accuracy analysis

INTRODUCTION

Satellite-based communication systems for use in homes (Bly et al 2006) and cars have been adopted by consumers in many parts of the world. The SafeTRIP project aims to build on this success and utilize a new generation of satellite technology to improve the safety, security and environmental sustainability of road transport.

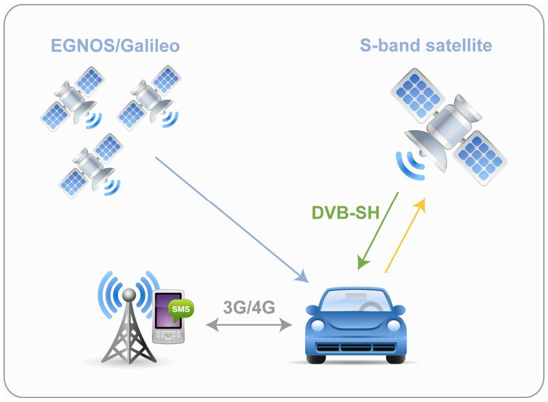

Figure 1. The SafeTRIP concept.

While being open and capable of integrating other communication technologies (such as Ground Networks), SafeTRIP exploits the S-band frequency range (Figure 1), which is optimized for two-way communication for on-board vehicle units. The S-band communication requires only a small omni-directional antenna on the mobile unit - making it suitable for the mass market. Existing solutions that use other frequency bands (for e.g. Ku-band) and different satellite communication require larger antennas thus being less suitable for integration in vehicles. As part of the SafeTRIP project, an open SafeTRIP platform is being implemented to host services for improved safety and navigation, but also entertainment and advertising to vehicle occupants.

During the project, the consortium has chosen to develop the full potential of this platform through extensive user requirements and technical research, experimentation and evaluation in field trials. To produce the best system, and to ensure that end users will benefit of this integrated system once deployed, SafeTRIP will develop and trial different applications in various contexts, evaluate benefits and opportunities for a range of stakeholders: individual travelers, transport businesses, emergency services, local and national government. At the end of the project, the platform will remain available, open and flexible – capable of using alternative communication technologies and integrate with existing and new ITS services.

SafeTRIP is an Integrated Project (IP) of 20 partners from 7 European countries, representing partners with a wide range of research and business and interests and expertise, coordinated by the motorway company Sanef of France. The total research effort is about € 11.5 million, with funding of € 7.9 million by the European Commission (DG Research). SafeTRIP started in October 2009 and will last 3 years; its main objective is to improve the use of road transport infrastructures and to optimize the alert chain in case of incidents – this will be achieved through an integrated system from data collection to safety service provision.

POSITIONING TECHNOLOGIES IN ITS

Current ITS applications are mainly infrastructure oriented and mostly based on roadside sensors. Information about the traffic flow cannot be collected based on floating car data or on acquiring location data from individual vehicles yet. However, assuming that in the future all vehicles will be equipped with positioning and communication (to transmit location data) system, these applications are to be considered. Current GNSS systems provide the sufficient coverage and accuracy.

In the field of ITS, individual navigation systems have to be definitely supported by positioning solution. Recent systems make use of GNSS technology; the developments put emphasis on enhanced solutions by receiving corrections from different positioning systems, in order to improve accuracy by Satellite Based Augmentation Systems (SBAS) and/or Ground Based Augmentation Systems (GBAS).

GNSS technologies are primarily GPS based, i.e. on the system that is operated and owned by the US Department of Defense. Countries with substantial experience and improvement in their own satellites have and are currently developing their own global positioning system: Galileo (Europe), GLONASS (Russia), Compass (China), IRNSS (India). In the European market even more devices are capable of receiving GLONASS and Galileo signals, as well as exploiting SBAS possibilities (EGNOS in Europe, WAAS in the US, MSAS in Japan).

While GNSS technologies are primarily based on the same of calculating the position on Earth by measuring distances from satellites, GSM-based positioning use various methods; 2G, 3G and 4G systems have different base station network architecture regarding the GSM cell sizes, base station density, etc.

TEST MEASUREMENTS

Independent tests have been carried out by two SafeTRIP partners. PIAP conducted tests on the road network in rural areas of Spain and Poland, while BME conducted tests in urban environment and on motorways in Hungary.

PIAP's tests were focused on testing the GNSS receivers according to applicability and accuracy. BME compared the code and phase measurement methods by receiving both GPS and GLONASS signals and analyzed the coverage in urban environment.

Outdoor tests were performed in two different geographical areas in order to evaluate the coverage of satellite signals under different longitude and latitude values in Europe:

- Poland was chosen as a test site to be representative of European north geographic area.
- Spain was chosen as the other test site to be representative of European south geographic area.

Stationary tests were done only in Poland while tests in mobile vehicles were performed in both countries. During the field tests a typical automotive patch active antenna was used. GNSS signal received by the antenna was transmitted to active antenna splitter and then to 4 particular receivers that were investigated during the tests (Figure 2).

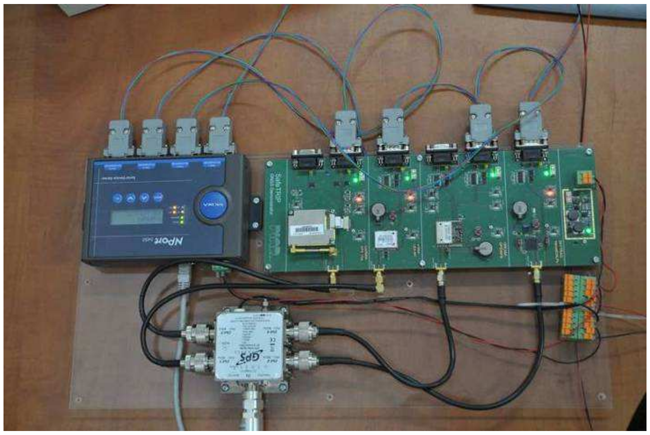

Figure 2. GNSS board.

In Parallel, while GNSS board was live, a reference data source was used for gathering reliable comparative data using a reference Novatel receiver. Four data streams from the tested receivers as well as the reference data stream were gathered in a data logger for further analysis in PIAP laboratory.

SBAS was available in all locations where tests were performed in Poland (at Poznań, Konin, Kutno, Skierniewice, Warsaw, Łomża, Białystok) and in Spain (from Murcia to Almeria, Malaga, Gibraltar, Cadiz).

Budapest Measurement Tests

Tests have been carried out at night in Budapest. A navigational Garmin and a TOPCON RTK receiver were used at 0.5 Hz measurement rate with external antennas mounted on a passenger car (Figure 3).

Figure 3. Test equipment mounted on vehicle.

The urban part of the test-drive consisted of road segments that are surrounded by high buildings blocking the sky visibility. The RTK measurements were surprisingly successful compared to previous tests with older receivers, although in many city roads only the navigational unit provided position. Tests on motorway focused on short time signal losses, e.g. passing under a flyover.

GSM-based Positioning Tests

The scenario where no GNSS based positioning is available was also investigated. There are many methods to derive positioning information (e.g. angle of arrival, time delay methods - Brimicombe and Li 2009) based on data provided by a single cell-phone, but most of these require specific hardware that need to be installed by the network provider. In order to avoid these requirements the method of network cell identification was used. It is a network-based proximity positioning method, also known as Cell Identifier (CID), Cell of Origin (COO) or Cell Global Identity (CGI) method. This approach identifies the approximate position of a mobile device through locating the cell base station that is currently used. The position determined by the network is not necessarily the co-ordinates of the geographical centre of a cell, but the mast location of the cell, and the size of the cell.

The GSM-based location data logging was done by the software called Antennas (http://www.panix.com/~mpoly/android/antennas/r1.0/) running on a cell-phone Samsung Galaxy S (Android OS).

During the GNSS measurements a mobile phone logged the actual GSM cell information from which the locations of the particular cellular antennas were being derived. Because most of the network operators consider this information as confidential, the database of the opencellid.org site was used. Note that the opencellid.org database doesn't contain information about the cell's size for the particular area where the tests have been done.

DATA PROCESSING

For the evaluation of different receivers, PIAP used a reference receiver and mapped the positions of all GNSS device sources.

An important parameter to measure was the time necessary to calculate the current position. Hot start receivers can produce the current position in less than 1 second. It takes much longer (from 30 to 40 seconds) if the receiver has a cold start. It depends on what kinds of information are available and what is actually stored in a chipset (initial time, initial position, almanac, ephemeris data). All chipsets available on the market give similar results of TTFF (Time To First Fix) (Table 1). The tests performed include measurements of reacquisition time after leaving tunnels which could be a very important parameter especially in dense urban environment.

Table 1. Typical TTFF

Chipset	Hot start	Cold start
Venus	1 s	29 s
Orcam	1 s	35 s
U-blox	1 s	28 s
Garmin	1 s	40 s

Accuracy is a measure that describes the difference between obtained positions and real positions. In other words it is the degree of closeness of obtained measurement to the true value. The stationary test was performed in PIAP laboratory (Warsaw, Poland). The accurate position of an antenna used for experiments was determined with geodetic GNSS receiver that respects Polish National Geodetic Coordinate System. The results show that all tested receivers have different accuracy.

Precision is a measure of reproduced consistency – determined by taking repeated measurements in unchanged conditions to see whether same or similar results are produced (i.e. the ability to be reproduced consistently). For every receiver the distance from each measured position to average position obtained by this receiver was calculated. Then the average value of this measure was calculated. Obtained results are presented in Table 2 below.

Table 2. Average distance from average position (precision)

Chipset	Average position error (accuracy)	Average distance from average position (precision)
Venus	0.677 m	1.222 m
Orcam	2.118 m	0.918 m
U-blox	0.400 m	1.146 m
Garmin	4.188 m	0.460 m

All four receivers satisfy basic requirements (10 m positioning accuracy, according to SafeTRIP system requirements), however some of them have significantly better performance in some tests.

Generally, two kinds of receivers could be distinguished:

- Accurate and fast (U-blox, Venus),
- Precise (Garmin, Orcam).

In summary, the U-blox receiver was found to be faster and more accurate, therefore it is definitely satisfies the positioning requirements of most applications. Additionally it is capable of receiving Galileo signals.

GIS Analysis of GNSS Measurements

The comprehensive analysis of the code and phase-measurement is based on comparing the positions of both the navigational and RTK receiver by mapping them on the same map. Raw data were transformed to the same reference system (Hungarian National Projection System) and then loaded into GIS software (Intergraph Geomedia and the open source Quantum GIS were used for that purpose). The trajectory shows that the test path went through the downtown of Budapest and also contained a motorway segment (Figure 4) (Orosz 2004).

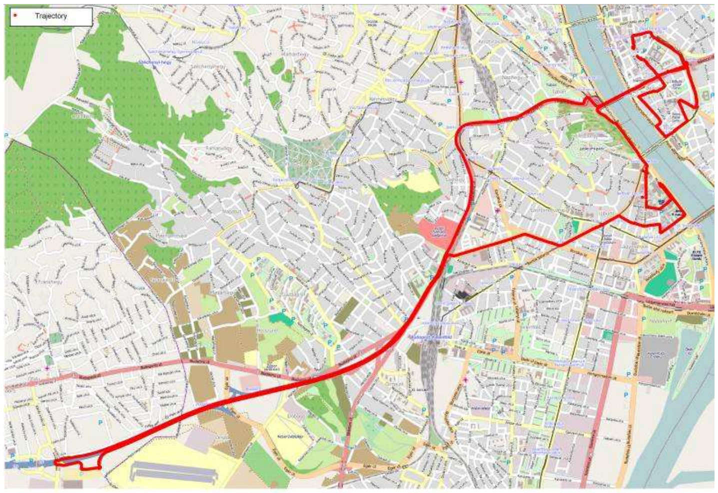

Figure 4. Test trajectory.

Besides the geometric information, GIS enables the analysis of various attribute data that also have been collected during the measurement. In addition to coordinates, the GNSS receivers' NMEA messages contain information about the number of visible satellites, DOP values, etc (Husti et al. 2000).

This information can be mapped in GIS and therefore it is possible to find correlation with the surrounding environment (Figure 5).

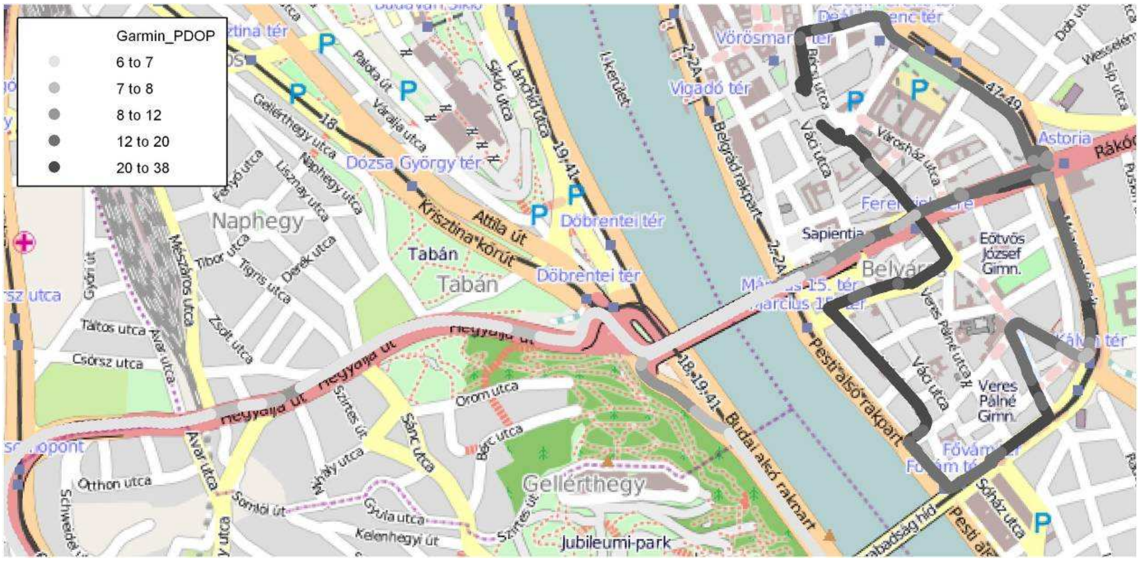

Figure 5. Mapping the DOP values in Budapest.

In the downtown of Budapest tall buildings block the visibility of the sky, therefore high DOP values can be observed in dense urban areas (Figure 5).

Receiving signal of multiple systems can improve the territorial coverage, thus it is interesting to map the number of visible GPS and GLONASS satellites (Figure 6).

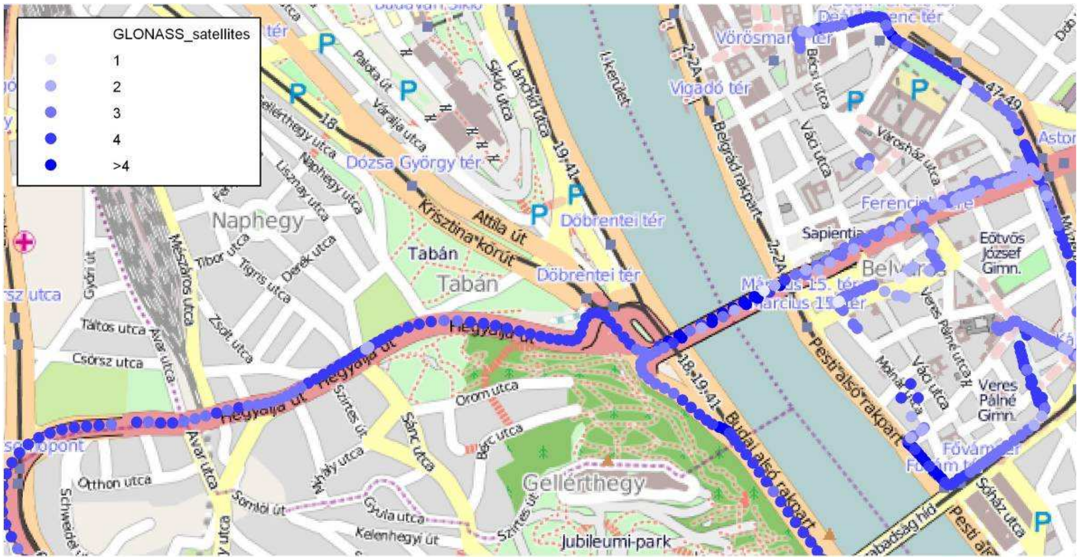

Figure 6. Mapping the visible GLONASS satellites.

However, a number of applications require lane-level navigation and thus meter-level accuracy. In open roads with clear sky visibility, these applications can be supported with enhanced positioning systems that involve SBAS. The test area was close to BME that has an EGNOS station on the roof of the main university building (Ádám et al. 2004). The TOPCON device received the EGNOS signals and the post-processing confirmed that such complex positioning meets the demands of most ITS applications. Since the primary purpose is to specify suitable GNSS solution for particular ITS application, no geodetic measurements were used for validating the GNSS accuracy; the map background (an OpenStreetMap segment) were used as reference instead.

Clear line of sight cannot be ensured in urban environment or even on motorways. Two types of signal losses were identified:

- duration of 2-4 seconds, e.g. passing under a flyover,
- duration of more than 10 seconds, e.g. in narrow streets among tall houses.

All signal losses have been found in the database and then mapped in GIS. It can be seen that even the RTK receiver at 0.5 Hz measurement frequency catch up the signal after 2-4 seconds after losing it by passing a flyover in the motorway (Figure 7) (Ferencz 2007). Such obstacles did not even affect the Garmin measurements.

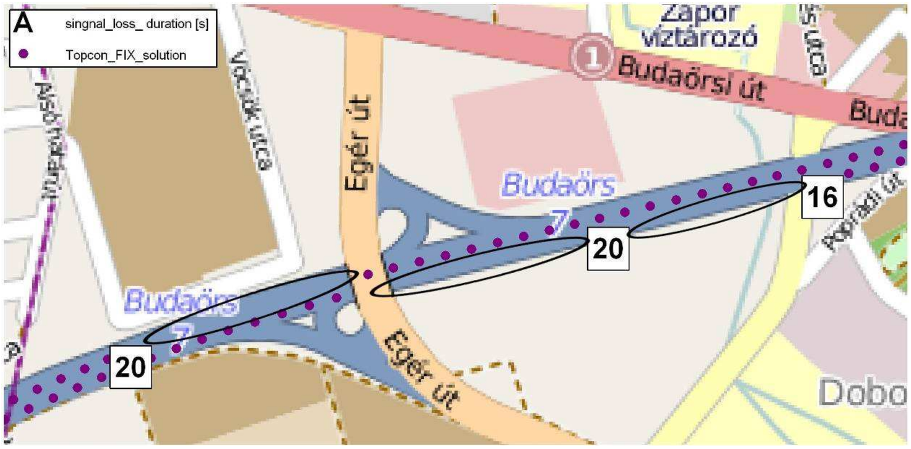

Figure 7. Mapping the signal losses (duration is seconds).

Processing GSM Data

The raw measurements logged by the phone contain the following information: type of the network (e.g. UTMS), network provider (e.g. T-mobile), LAC (Location Area Code), CID (Cell ID) and signal strength. First of all the synchronization between the position information provided by the GPS receivers and the cell information has to be ensured. In order to achieve a fully synchronized dataset, timestamps were used.

To identify the network operator a five digit number was logged with every cell position (e.g. 21630) that could be divided into two parts. The first part is the country wide Mobile Country Code (MCC, in Hungary 216), the second part describes the network provider and called Mobile Network Code (MNC, in Hungary e.g. T-mobile: 30, Telenor: 01). This investigation doesn't deal with the analysis of the different coverage of each provider, this can be the goal of further investigations.

In order to derive the exact location of the cell's mast, the LAC and CID information were used. Since the network providers in Hungary haven't started an official location information service yet, and because of the fact that the network providers consider cell's (mast's) location information as confidential, the freely accessible database of the opencellid.org was used.

With the derived position information of the cells and by using the position information provided by the GPS receivers the measurements could be mapped (Figure 8).

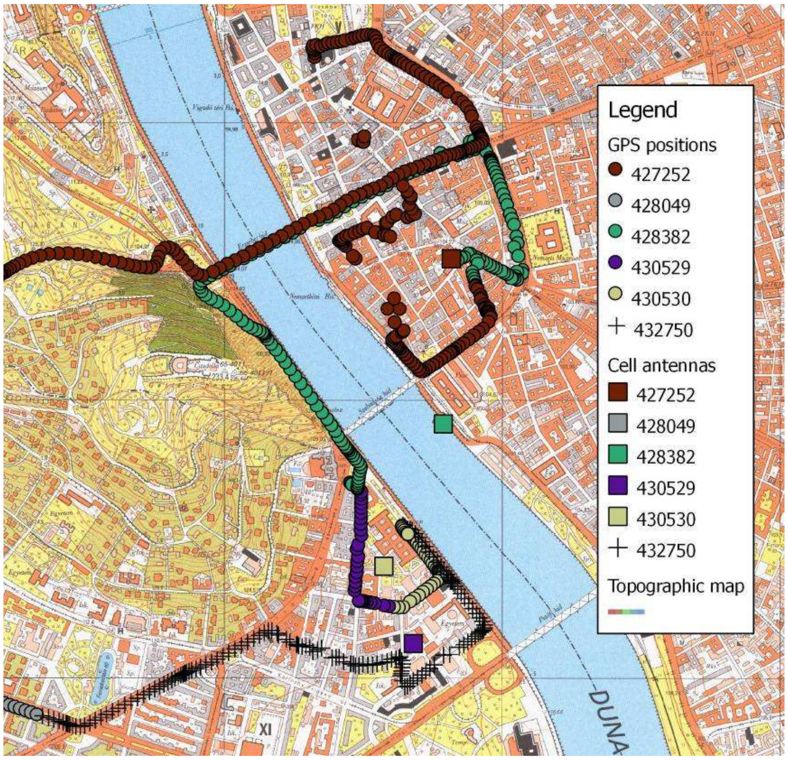

Figure 8. Mapping Cell IDs to geographical locations.

As it can be clearly seen on Figure 8, in urban environment the phone changed cell more often; in urban areas more antennas are deployed closer to each other not only in order to ensure coverage, but because of the high number of users. Moreover, there are not only omni-directional antennas (providing 360° horizontal coverage), but directed antennas as well.

The main goal of the investigation was to determine whether GSM based positioning could be used as an alternative in deriving location information in areas where the application of GNSS is limited (e.g. in urban canyons) or impossible (e.g. in underground garages), and the required positioning accuracy is around the size of a building block (100-300 m). The high coverage of the GSM networks, and the almost cost-free measurements (the mobile subscription penetration in Hungary is over 100%) makes the technology applicable as an alternative locating method

RESULTS

For many ITS services the commercial navigational receivers provide sufficient accuracy. However, in tunnels or in garages the positioning has to be supported by an independent system, e.g. GSM-based positioning. Most services require wide coverage rather than cm-level accuracy. Accuracy at 30-40m meter level is appropriate for services such as tracking coaches or public transport vehicles.

RTK measurement's main advantage is the improved accuracy. On the other hand, RTK capable devices are much more expensive than navigational units. Besides, communication technique is required to receive corrections real-time.

Several services will be implemented and demonstrated within the SafeTRIP project to highlight the benefits of the SafeTRIP platform. The services have been formulated based on extensive user requirements capture (SafeTRIP 2010). Table 3 summarises the positioning requirements for each of them.

Table 3. Positioning Requirements for SafeTRIP services

Service	Description	Accuracy Required	Interval between updates	Coverage Required
Fleet management	This service provides tracking of commercial vehicle such as coaches, trucks and patrol vehicles.	50m	Not available	Global & mostly outside cities
Emergency Call	This service can trigger an emergency call if a collision is detected. It also allows an occupant of the vehicle to trigger an emergency call by pressing a button. The vehicle position along with other information is then relayed to the authorities or to a third party.	1-15m	Not available	Global
Stolen Vehicle Tracking	This service allows a stolen vehicle to be tracked.	1-15m	15-20 seconds	Global
Road Side Assistance	This service allows the occupant to request assistance in case of breakdown or medical emergency.	1-15m	Not available	Global
Coach Tracking	This service will allow Eurolines (a coach company) to track its coaches across Europe.	50m	Ideally 1 min but can tolerate intervals up to 10-15 minutes	Global

It can therefore be deduced that most services do not require geodetic-level accuracy, but do need reliable positioning solution with broad (territorial) coverage. For instance many fleet operators have trucks and coaches travelling across the Europe to Russia, Middle East and North Africa – and it is paramount for safety and logistics reasons to know there the vehicles are at all times.

GSM-based positioning solution could be useful in dense urban areas and anywhere on the road network with no clear sky-visibility for applications where high accuracy is not essential and other positioning solutions are not available.

CONCLUSION

Most of the SafeTRIP services can be supported by GNSS positioning. The widely used, inexpensive navigational receivers are capable of ensuring the desired accuracy, therefore there is no need for applying geodetic and RTK receivers for such intelligent transport systems.

There are a number of situations where visibility to the satellite is reduced or is unavailable as described earlier. In the case of the Emergency Service, the speed of response depends on a number of factors which includes knowledge of the position of the vehicle involved in an accident. In the event that GNSS is not available, GSM-based positioning offers a chance to save lives. This is critical for accidents that happen in tunnels – where the chance of survival decreases very quickly with time. In addition, during adverse weather conditions (e.g. snow) when accidents and breakdowns are more likely, reduced visibility of the sky can affect GNSS positioning. Therefore, for such services, GSM-based positioning can be used as a fallback method.

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