An Evaluation of European SBAS, EGNOS, complemented with SISNET-GPRS within urban areas

Benito Ubeda; Antonio G. Skarmeta; Miguel A. Zamora; Juan P. Canovas; Javier Perez
Murcia University. Facultad de Informatica. Campus de Espinardo.
30071 Murcia
Tel: +34 968 36 4623 - Fax: +34 968 364151
E-mail: bubeda@um.es

ABSTRACT

In this paper we present the results obtained in our evaluation of EGNOS-SISNET-GPRS combination in applications related to terrestrial transport within urban areas. In our approach we have developed a prototype where we combine a GPS-EGNOS receiver, SISNET access point, GPRS link, and the use of a prototype car developed for testing purposes. In this technical paper we show the results and conclusions about their viability in some ITS application areas.

I. INTRODUCTION

Many ITS land applications such as road pricing, fleet management, vehicle navigation and tracking, etc. need precise positioning and affordable low cost on board units, OBU. The use of global navigation satellite systems, GNSS, sensors provided with capacity of wide area real time augmentation satellite based, SBAS, (1,2), is the most realistic solution to achieve this purpose, specially for open environments such as highways. But, if the vehicle is running through urban environments, data misleading appear and the use of this sensor alone is not feasible. This is due to the high density of tall buildings that break the line of sight between satellite transmitter antenna and sensor receiver one. Effects, such as fading and multipath for signal in space, SIS, are the most significant.

Introduction of inertial sensors combined with GNSS, is the best technical solution but is too the most expensive and complex. Another proposed ways is the use alternate communication channel to transmit correction messages to OBU, that is, the use of cellular network, CN, broadcast FM stations, etc. (3)

In this way, SISNeT project, developed by European Space Agency, ESA, is a new promising technology that is necessary to test. (9)

In this paper we present some results obtained in our evaluation of EGNOS-SISNET-GPRS combination in a specially problematic environment: urban trajectories.

A. State of the art

The use of global navigation satellite systems, GNSS, based sensors for position calculation and navigation utilities, are basic for the success of ITS. Today, only two independent GNSS are operatives: The Global Positioning System, GIPS, and the Global Orbiting Navigation Satellite System, GLONASS, although the European Union, EU, have scheduled a third independent GNNS for year 2008, the GALILEO project (4,5).

Actually, to improve the precision, differential techniques may be used in order to cancel some spatial and temporal correlated effects such as ionospheric RF propagation. One of this are the Satellite Based Augmentation Systems, SBAS, (6,7). These was developed with the purpose of increase, in real time, the accuracy, availability and integrity in a wide region of coverage. The most popular of these systems are the Wide Area Augmentation System, WAAS, (8), implemented in USA and the European Geostationary Navigation Overlay Service, EGNOS, implemented in Europe. (4).

EGNOS System Test Bed (ESTB) is the EGNOS prototype. It is broadcasting a signal in space, since February 2000 with a PRN 120 on AOR-E geostationary satellite. ESTB transmit messages with contents conforms to RTCA/DO-229B dated October 06, 1999 with some exceptions. There are four possible modes:

- mode 0 : GIC/WAD messages and ranging.
- mode 2 : fast corrections and ionosphere corrections plus Ranging.
- mode 3 : fast corrections and ranging.
- Ranging mode

ESTB is used to support and test the development of the EGNOS system, to demonstration toward potential users and to test the possibility of expanding this system outside Europe. It provides users with a GPS-augmentation signal that enables them to calculate their position to an accuracy of a few meters.

Thinking in land ITS application at urban areas, the European Space Agency, ESA, launch the SISNeT project, (9). SISNeT gives access to the wide-area differential corrections and the integrity information of EGNOS by internet. The SISNeT project was undertaken by ESA during the second half of 2001. In August 2001, the first prototype of the system was set-up, and the SISNeT concept was successfully validated. Since February 2002, the system has been pre-operational, broadcasting an EGNOS-like signal through the Internet, as generated by the EGNOS System Test Bed, ESTB, in nearly real time.

The four main components of the SISNeT platform are:

Base Station, BS: A PC computer connected to an EGNOS receiver through a serial port. Several software components are installed on the computer, so that EGNOS messages can be obtained and sent to a remote computer, called Data Server, in real-time.

Data Server, DS: A high-performance computer, optimised for running server applications with many users connected at the same time. The DS functionality is implemented through a software application called SISNeT Data Server, SDS. This software receives the EGNOS messages from the BS and transfers them to the remote SISNeT users in real time. In addition, the SDS implements all the extra services, present and future, provided by the SISNeT system to the users.

User Application Software, UAS: A software application; which design complies with the SISNeT User Interface Document specifications. The UAS obtains EGNOS messages in real time (1 message/s or 250 bit/s) from the DS. The UAS can also access and apply the present and future additional SISNeT services. Each concrete SISNeT-based application is characterised by specific processing and output interface stages, which provide the desired functionality and user interface to the UAS. The software can be embedded in different kinds of computers and electronic devices, e.g. Personal Data Assistants.

Web server: The DS can store the received messages in a remote Web server via the FTP protocol, enabling future development of Web / WAP applications, accessible to the users through a Web browser or mobile device.

For mobile access, the use of Cellular Network, CN, such that General Packet Radio Service, GPRS, may be the best election actually and we tray to verify. Firs trial in Finland has been presented (10) with a GSM modem.

II. EXPERIMENT PLANNING

A. Objectives

One of the main interests of this research has been to use a SBAS as one of the main onboard sensor for Satellite Positioning System, SPS, and navigation systems in safety driving applications, (11), and other ITS services. The future task is to integrate the information of different sensors, GNSS, digital maps, inertial sensors, etc. in order to be able to obtain, in urban areas, the position with great availability, accuracy and precision, and in that way to be able to a broach ITS services such as roadpricing, urban traffic management and control, electronic fee collection, emergency and incident handling, etc.

Initial objectives was:

1. Construct a software application tool for monitoring GNSS sensor status, data log of trajectories and communications utilities.
2. Using an GNSS/SBAS EGNOS high end sensor, study the coverage problems along a city, such as Murcia.
3. Adding SISNeT/GPRS capability analyse the improvement along de same trajectory.
4. Conclusions.

B. Software application developed.

The software application offer the user a way to know, by means of a graphical interface, at any time the state of the GPS subsystem: if calculated position is valid, how good the solution is, etc. The GPS monitoring utility of the University of Murcia currently works in 2 modes: real-time monitoring of the GPS receiver (“online”) or it can work “offline” with the receiver’s logs.

Up to now the following features are included:

- HPL (Horizontal Protection Level) Graph: it shows the evolution of HPL (HPL is a measure of the integrity of the position being reported) through the time.
- UTM (Universal Transverse Mercator) graph: it displays all the solutions generated by the receiver in <x,y> coordinates.
- Absolute Error graph: If we are in static positioning, it shows the absolute error of the computed solution given the exact position.

- Satellites diagram: it draws in real-time a polar diagram with the visible satellites, “sky plot”.
- Position: It gives back the present calculated position in Latitude-Longitude-Height format.
- Alarm traffic light: It turns red when the HPL surpasses the 30 meters, otherwise it will appear green.
- -Position type label: It shows at any moment if the calculated position is WAAS-GEO, WAAS-SISNeT, single point or if no position could be computed.
- -Send Commands to the GPS receiver through the serial port link; also the user can request a list of all available commands.
- -Upon conclusion or even during a work session if we are in “online” mode, the user may displays to the complete graphs of the HPL, UTM, and absolute errors values. Furthermore, it is possible to dump these values to a text file.

Figure 1 shown the graphical aspect of our software application.

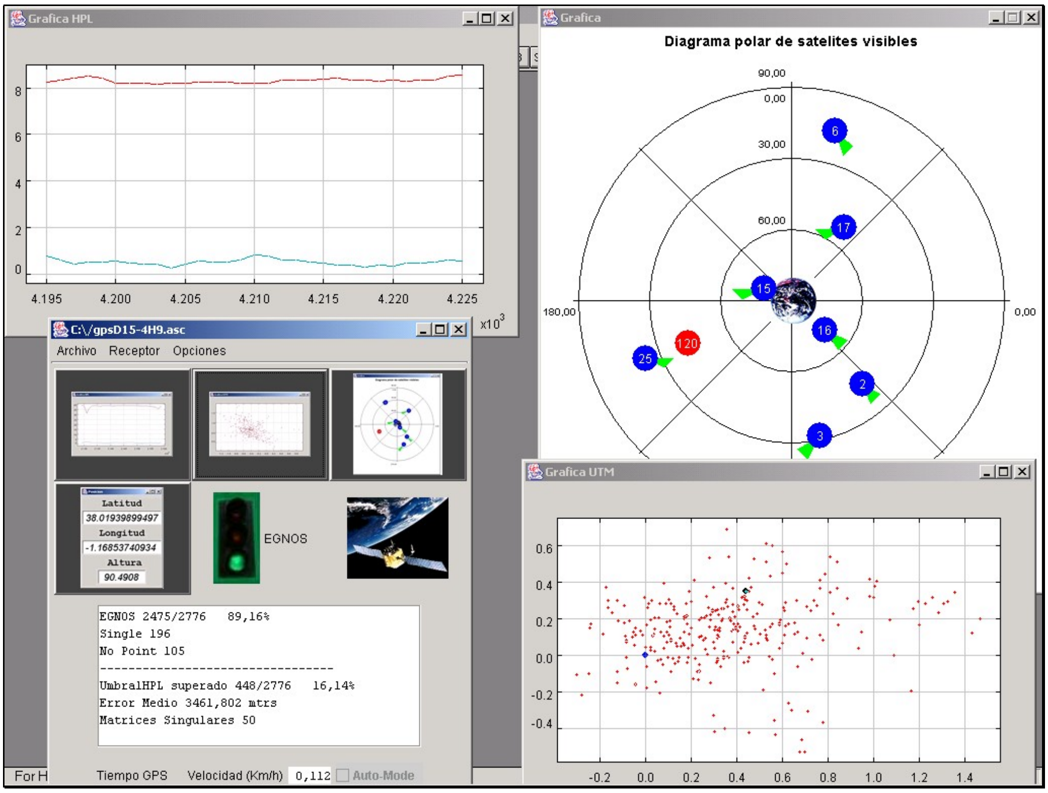

Figure 1. Graphical User Interface of GNSS Monitoring tool developed.

For SISNeT access, there are two parts: a DS2DC client (Server Data to Data Client) who connects to the Data Server (DS from now on) to obtain EGNOS messages in real time, and the application himself, that will process the messages in the form and way that the user settles down. In our case; injecting those EGNOS messages in a GPS/SBAS receiver in order to obtain improved positioning.

The DS2DC client has to conform strictly to the SISNeT specifications so that it is functional. The appearance of SISNeT UAS developed is shown in figure 2.
For some post process and graphics generation, the well know Matlab package has been used.

Figure 2 University of Murcia SISNet UAS

C. Hardware implementation

The OBU that we are used in our experiments include a high end EGNOS sensor, Novatel millennium OEM-3, (12), working in a single band, a GPRS/WLAN board Nokia D211, specifically designed to insert in a PCMCIA slot and a laptop computer. In figure 3 we show the vehicle and some hardware used in this research.

Figure 3.- (a)Vehicle Comarth S1-50. (b) GNSS sensor, Novatel. (c) GPRS/WLAN board

III. MEASUREMENTS

A. Static measurements

Initially we make static measurements to obtain conclusions on the accuracy, availability and integrity of the ESTB SIS in this area of Spain. Initially, for road ITS application, only horizontal specifications we are analysed, that is, horizontal accuracies given as circular error probability (CEP) and horizontal integrity given as horizontal protection level (HPL). Another usual statistics used are the RMS, similar to 1 sigma with a probability of 67% if the position is unbiased and 2drms, or 2 sigma with a probability of 95%.

The first task was to get a representative log for a reference static position, with data rate of one measurement each second (1 Hz). This log contain computed position, satellite range measurements, position of each visible satellite, etc. necessary to compute the parameters that we need to analyse.

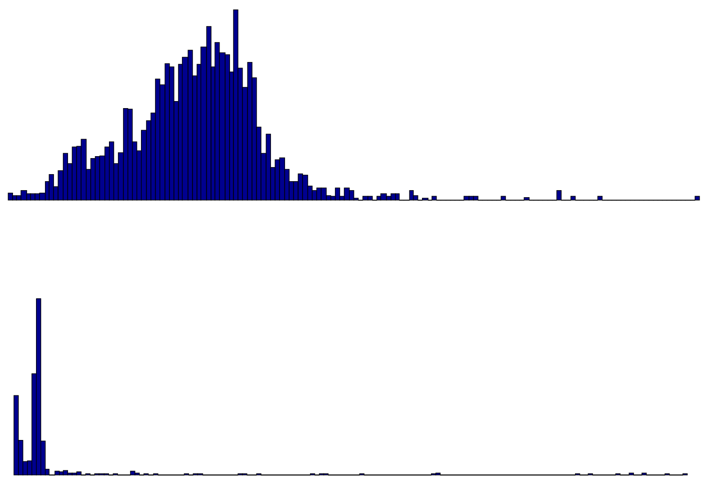

Figure 4. HPE and HPL distributions

Figure 4 (upper part) shows histograms of the horizontal position error (HPE) in meters, and (lower part) the horizontal protection level (HPL). In order to define the integrity we have initially use the MOPS definition of integrity for air navigation in the approaching phase of aircrafts. Although it is a very strict measure it could serve to give and indication of the usability of the EGNOS signal in road navigation. The accuracy obtained in the majority of our measurements was good: the mean horizontal position error was 1.25 m, with good precision (standard deviation σ=0.46 m). However, the integrity parameter, HPL, presents a median , HPL50%=21m and poor dispersion (σ=36 m) The mean error of 1.2 m obtained in the positioning with EGNOS complemented with other sensors information, may be adequate for a broad range of Intelligent Transport Systems (ITS) applications, e.g. to know in which motorway lane we are driving, or at what crossroads the vehicle needs to turn right or left.

B. Dynamic trajectories with EGNOS alone

In a second step we install the sensor on board the MIMICS car to proceed to study the availability, integrity and precision obtained in some urban trajectories with only EGNOS and aided with GPRS-SISNeT utility.

We configured an onboard unit (OBU), with the GPS receiver, an antenna, personal computer and other sensors in the MIMICS vehicle and next we proceeded to circulate with the car through different trajectories in order to acquire some logs around Murcia city. The first task was to select a typical urban trajectory to show some representative problems in position determination: complete or partial GPS SIS blockage, geo SIS for EGNOS correction blockage, multipath, etc. Figure 5 show a map with part of the trajectory we have follow for about 15 Km.

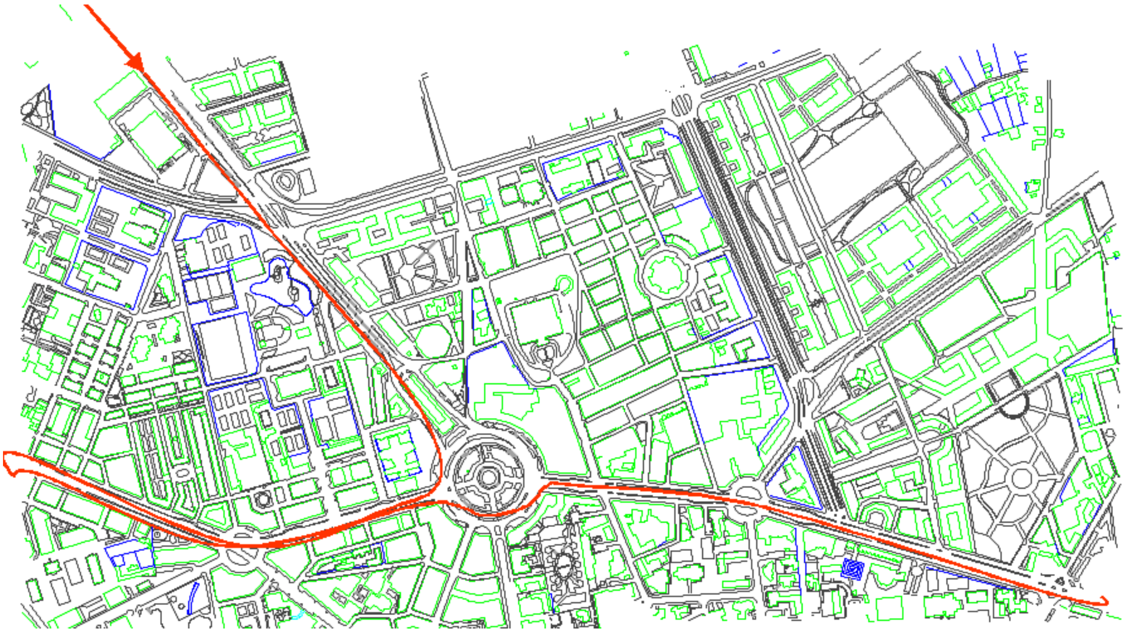

Figure 5. Trajectory detail over map

We have make many trials, at different days an hours. All data logged for similar trajectories are sufficient significant to get some conclusions. Figure 6 shows a typical trajectory data log, where the SIS at GNSS sensor is blocked in some section total or partially. The green line represent zones where EGNOS SIS have a good coverture and the blue line, represent those with EGNOS SIS blocked.

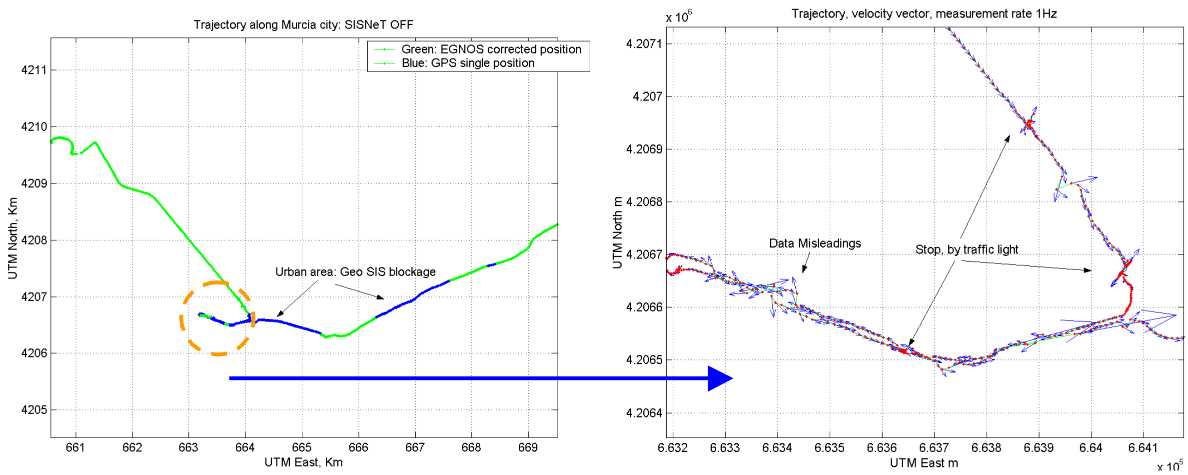

Figure 6. Trajectory recording with SISNET OFF.

Table I Summary for EGNOS log.

Data points logged. Rate 1 Hz	1914	
EGNOS corrected data	1133	59.2%
Single position	739	38.6%
No solution	42	2.2%
Points with Integrity conditions. HPL<30	1463	76.4%
Distance	14275 m	

In table I we report some results. We see that only the 2.2% of the time the sensor is out of service. The 59.2 % of position has been corrected by EGNOS and the integrity is about 76%.

Next figure show the carrier to noise level for each visible satellite from location. Specially for GEO, we show the high degree of blockage.

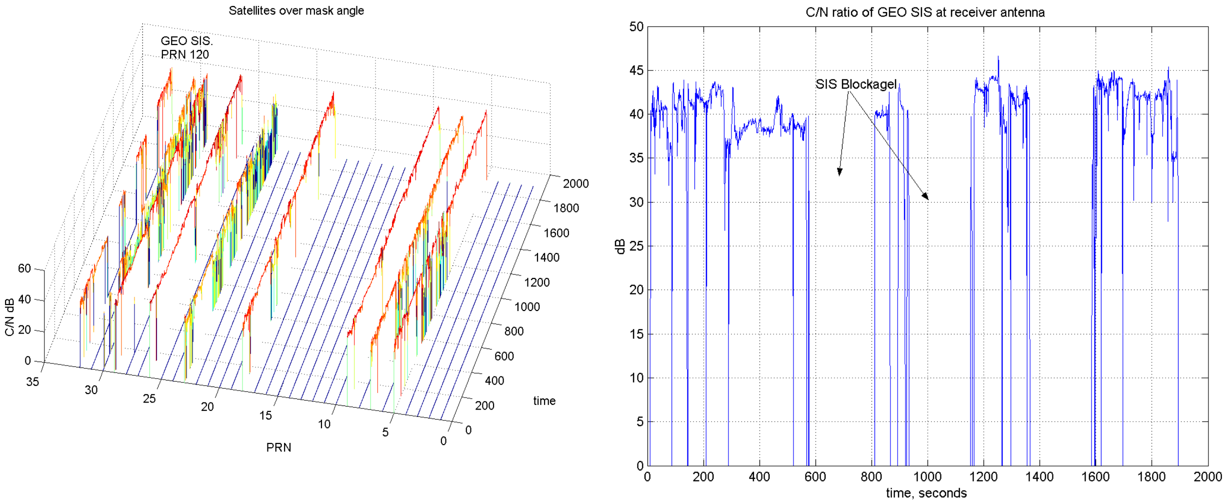

Figure 7. Obstruction for signal in space.(a) All PRN. (b) Geo SIS fading

C. Dynamic trajectories with EGNOS/SISNet-GPRS

With SISNET active in mode auto, that is, if GEO SIS is present, then SISNeT is switch off, but when the system detect that GEO SIS is blocked for five seconds, SISNeT is switch on. Figure 8 shown approximately the same trajectory.

We choose auto mode for two reason: the GPRS cost is function of amount of bits transmitted and because geo sat may increment de availability of GNSS sensor.

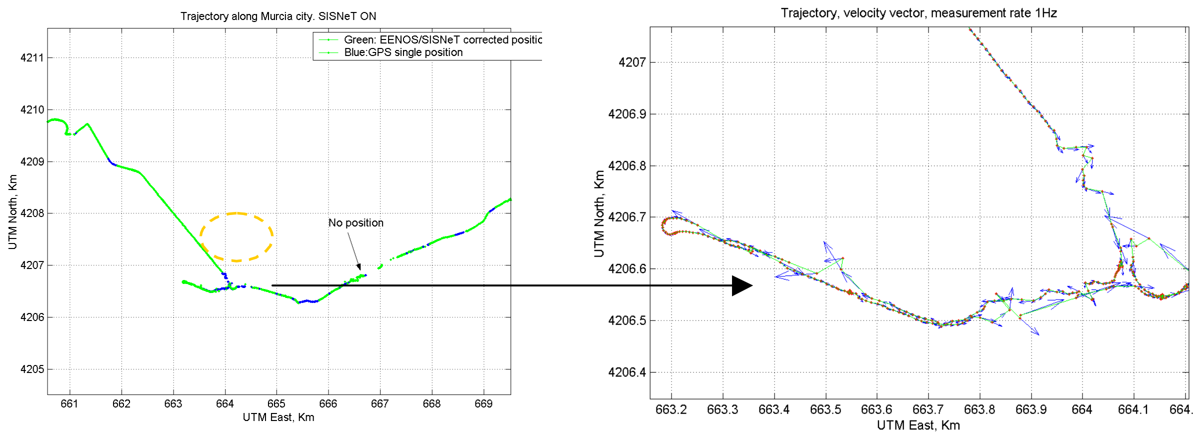

Figure 8. Trajectory recording with SISNET ON. Mode auto.

Table II. Summary for EGNOS/SISNeT/GPRS log.

Data points logged	2042	
EGNOS corrected data	1375	67.3%
Single position	343	16.8%
No solution	324	15.9%
Points with Integrity conditions. HPL<30	1125	55.1%
Distance	16393m	

We see that the portion of corrected data grow from 59% to 67% however no solution percentage is very high, that is, availability decrease.

The integrity parameter for GNSS/SBAS based sensor that we need to analyse in ITS is the horizontal protection level, HPL. Figure 9 show its aspect versus time along the trajectory, for both cases studied.

Due to the SIS blockage, the fast changing in the number of satellites used in the solution cause data misleading in position determination for sporadic insufficient number of sat. On the other hand, fast fading of geo SIS involve a continuous switching between communication channel, EGNOS/SISNeT, with data source for wide area differential corrections. This and delays in the internet -GPRS transmission will cause the low integrity percentage.

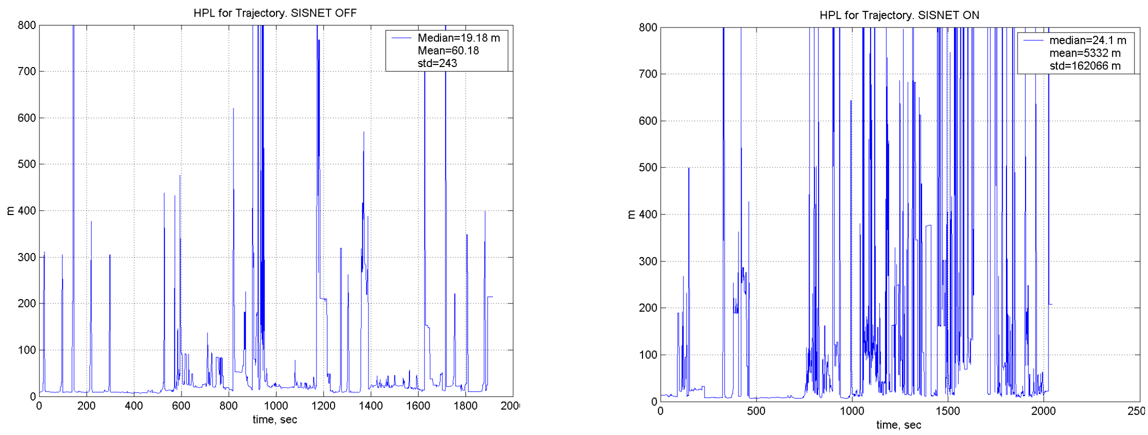

Figure 9. HPL versus time. (a) Only EGNOS. (b) EGNOS/SISNeT

That is, It may happen that -- due to the transmission over the internet or for any other source of error, some of the messages are lost. Although not usual, this situation may occur, the collateral effect being that the HPL graph shows peaks of high value.

We need to remember that SISNeT doesn't focus on safety-of-life applications (integrity) but principally it is designed to improve accuracy. This is because the time delays introduced by the internet are not compliant with safety critical time constraints.

IV. CONCLUSIONS

Tests have been made to determine if there is any real benefit in getting the EGNOS signal via Internet; as the profit of a GPS+EGNOS versus the simple GPS has been already thoroughly proved.

Urban areas such as large cities provide a challenging environment for GPS receivers. These areas are populated with tall buildings that limit sky visibility and contribute to heavy multipath conditions.

The combination GNSS/SBAS/CN seems to be the best solution for develop a ITS services in urban areas. In this way SISNeT is a valuable tool for navigation services where a high degree of precision and accuracy in real time is a basic necessity.

In our research, some urban trajectories was studied. We have compared the log's obtained for GPS only, for EGNOS and for EGNOS/SISNeT.

The results of the experiments presented in this paper show that the use of the EGNOS complemented with SISNeT-GPRS increase the availability and precision for real time navigation systems in urban areas but no increase the integrity. The inclusion of low cost INS sensor in the OBU is a basic necessity to obtain a high degree of integrity . The system is, in general, valid for most ITS applications, i.e., navigation, localization within a map, etc. but may be insufficient for automatic driving, trajectory data loggers for vehicle accidents, etc. due to low integrity.

We need to improve the mechanism for auto mode switching between EGNOS/SISNeT to get a smoothing data trajectories.

In addition it is necessary to take in mind that own signal EGNOS as SISNET even is in phase of test; SISNET 3.0 has been recently announced to improve the system.

Finally, we have make our research with a high end GNSS sensor, but, to get a competitive OBU, most navigation services in urban road transport need the use low cost an then, low accuracy. For applications that request the use of improved accuracy, availability and integrity, the GNSS/SBAS/SISNeT represent an actual improvement. Combination with low cost INS sensor is necessary to get a robust solution. In the future, when a third GNSS constellation, Galileo, will be a reality, may be, the use of GNSS only based OBU for ITS urban applications.

Acknowledgements

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