The ESA SISNET Project: Real-Time Access to the EGNOS Services across the Internet

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INTRODUCTION

EGNOS, the European Geostationary Navigation Overlay Service, is the first step on the European contribution to the Global Navigation Satellite System, and a fundamental stepping-stone towards GALILEO, Europe's own Global Navigation Satellite System. EGNOS is an augmentation system to the GPS and GLONASS satellite navigation systems, which provides and guarantees navigation signals for aeronautical, maritime and land mobile Trans-European network applications. Since January 2000, a pre-operational signal of EGNOS is available through the so-called ***EGNOS System Test Bed (ESTB***). The ESTB is a representative real time mock up of the final EGNOS system.

EGNOS will broadcast their wide area / integrity message through Geostationary satellites. The ESTB (EGNOS prototype) is already broadcasting the EGNOS message through the Inmarsat III AOR-E satellite (broadcast through Inmarsat III IOR satellite is also planned for this year). Satellite broadcasting through GEOs is proved to be an efficient strategy for avionic applications and other modes of transport. For some applications, though, GEO broadcasting may provide some limitations (e.g. building obstacles in cities or rural canyons may difficult the GEO reception). While the EGNOS message will still be very useful for those applications, a different transmission link may need to be considered to maximally exploit all EGNOS potential. For this reason, ESA has recently launched specific contract activities (through the Advanced System Telecommunication Equipment programme –ASTE–) to assess and demonstrate architectures where the ESTB signal is broadcast through non-GEO means (e.g. FM or GSM broadcasting) [1]. In this context, ESA has also launched an internal project to provide access to the EGNOS test bed messages through Internet. This Project, called ***SISNET*** (Signal in Space through the Internet), is the main purpose of this paper and it is described here in some detail.

A first prototype of the SISNET concept has been set-up by the ***ESA GNSS-1 Project Office***. This first prototype uses a PC computer to implement the user equipment software, and the connection to the Internet is achieved using a LAN environment (via a proxy server). A generic GPS receiver is connected to the computer through a serial port. The software implements the basic DSP for positioning improvement, and a Graphical User Interface, in order to demonstrate the accuracy improvement obtained with the use of SISNET, with respect to the GPS-only solution.

The SISNET project can grant noteworthy advantages to the GPS land-user community. A user equipped with a GPS receiver and a GSM modem can access the SISNET services, thus being able to benefit from the EGNOS augmentation signals, even under situations of GEO blocking. It is firmly believed by the authors that the access of EGNOS messages through internet and the possibility of using standard GPS receivers with EGNOS augmented performances, will open a large amount of applications for satellite Navigation; some of those will also be discussed through this paper.

EGNOS AND EGNOS TESTBED BACKGROUND

The European Tripartite Group (ETG)[1], (ESA – European Commission – EUROCONTROL) is implementing, via the EGNOS project, the European contribution to the Global Navigation Satellite System (GNSS-1), which will provide and guarantee navigation signals for aeronautical, maritime and land mobile Trans-European network applications. On behalf of this tripartite group, the ***European Space Agency*** is responsible for the system design, development and qualification of an Advanced Operational Capability (AOC) of the EGNOS system. EGNOS will significantly improve the accuracy of GPS, typically from 20 to 3-5 metres vertical accuracy, and to 1-2 metres horizontal accuracy. Moreover, EGNOS will offer a service guarantee by means of the Integrity signal and it will also provide additional ranging signals. For a complete summary of the EGNOS project and its status, the reader is referred to [2].

Since January 2000, a pre-operational signal of EGNOS is available through the so-called ***EGNOS System Test Bed (ESTB***). The ESTB is a representative real time mock up of the final EGNOS system. The ESTB architecture is presented in Fig 1. It consist of a space segment comprising nominally two transponders on board the Inmarsat-III Atlantic Ocean East and the Indian Ocean satellites, a ground segment comprising a number of reference stations spread over Europe and beyond, a processing centre and the Inmarsat uplink stations. Communication lines interconnect all stations [3].

The main objectives of the ESTB are the following:

- To have an assessment of the global performance achievable with EGNOS;
- To analyse in depth specific critical design issues or tradeoffs between several options;
- To develop and validate system test methods;
- To provide a representative tool for Civil Aviation;
- To demonstrate to the final users the system operation and to promote new satellite navigation applications.

Concerning the last objective (the promotion of satellite navigation applications), the ESTB has already been successfully used in specific aviation, maritime and land mobile application tests [4]. In addition, ESA has recently launched specific contract activities (through the Advance Telecommunications and Navigation Technology Programme –ASTE–) to assess and demonstrate architectures where the ESTB signal is broadcast through non-GEO means (e.g. FM or GSM broadcasting) [1]. In this context, ESA has also launched an internal ESA project to provide access to the EGNOS test bed messages through Internet. This Project, called ***SISNET*** (Signal in Space through the Internet), is the main purpose of this paper and it is described in some detail in next sections.

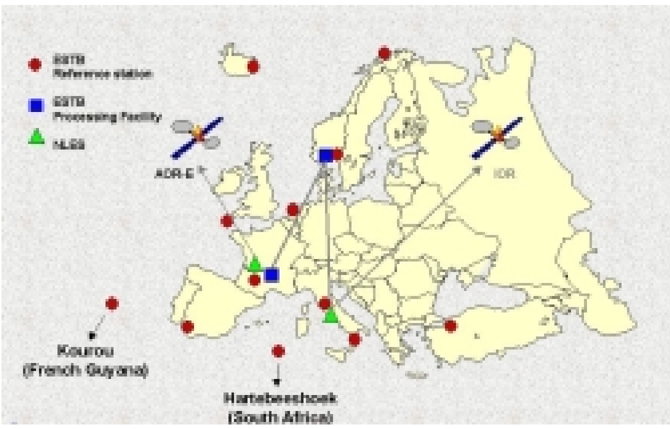

Fig. 1. The EGNOS System Test Bed architecture

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[1] A formal agreement based on article 228 of the EC treaty was concluded on 18.06.96 between the European Community, EUROCONTROL and ESA, for the development of the European Contribution to the first generation Global Navigation Satellite System (GNSS-1).

THE SISNET PROJECT

EGNOS will broadcast their wide area / integrity message through Geostationary satellites. The ESTB (EGNOS prototype) is already broadcasting the EGNOS message through the Inmarsat III AOR-E satellite, located at 15.5 degrees West. During this year 2001, the ESTB will also broadcast through the Inmarsat III IOR satellite, located at 64.5 degrees East. The GEO broadcast of the EGNOS messages is well regulated by the Standard and Recommended Practises (SARPS) produced by the International Civil Aviation Organisation (ICAO). Satellite broadcasting through GEOs is proved to be an efficient strategy for avionic applications and other modes of transport. For some applications, though, GEO broadcasting may provide some limitations (e.g. building obstacles in cities or rural canyons may difficult the GEO reception, etc). While the EGNOS message will still be very useful for those applications, a different transmission link may need to be considered to maximally exploit all EGNOS potential. In addition, the availability of the EGNOS signal through the Internet may also be of interest for people aiming at monitoring the EGNOS signal for statistics, off-line analysis or system performance assessment (through the connection of the EGNOS signal to real-time simulators [5,6,7]). For those all potential users, ESA has launched the SISNET project.

The main objective of SISNET is to provide access to the EGNOS messages, using a GSM wireless link (or any other kind of connection) to access the Internet. Some of the challenges of the SISNET system include:

- The SISNET project should not interfere at all the EGNOS/ESTB architecture.
- Connections to SISNET server need to be reliable and stable.
- The full additional delay due to the SISNET introduction needs to be minimised and controlled.
- Any generic GPS receiver should be easily upgradeable to benefit from the SISNET service.
- GPS receivers using SISNET should include specific functions to deal with potential delays or service interruptions.
- A GPS receiver working in SISNET mode should have enhanced performance versus a GPS-only receiver.
- A SISNET-enabled GPS receiver should be able to revert to GPS-only mode in case of Internet connection problems.
- The number of simultaneous users of SISNET should be controllable so that the system efficiency may be guaranteed.
- Others.

Assuming those challenges, a first prototype of the SISNET concept has been set-up by the ***ESA GNSS-1 Project Office***. This first prototype uses a PC computer to implement the user equipment software, and the connection to the Internet is achieved using a LAN environment (via a proxy server). A generic GPS receiver is connected to the computer through a serial port. The software implements the basic DSP for positioning improvement, and a Graphical User Interface, in order to demonstrate the accuracy improvement obtained with the use of SISNET, with respect to the GPS-only solution. A more detailed explanation of the SISNET architecture is described in next Sections.

ARCHITECTURE OF THE SISNET PLATFORM

Fig. 2 illustrates the SISNET platform architecture. The four main components of the system (depicted as computers) are the following:

- Base Station (BS). A PC computer connected to an EGNOS receiver through a serial port. Several software components are installed on the computer, allowing acquiring the EGNOS messages and sending it to a remote computer (called Data Server) in real-time.
- Data Server (DS). A high performance computer, optimised for running server applications with a large amount of connected users. 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.

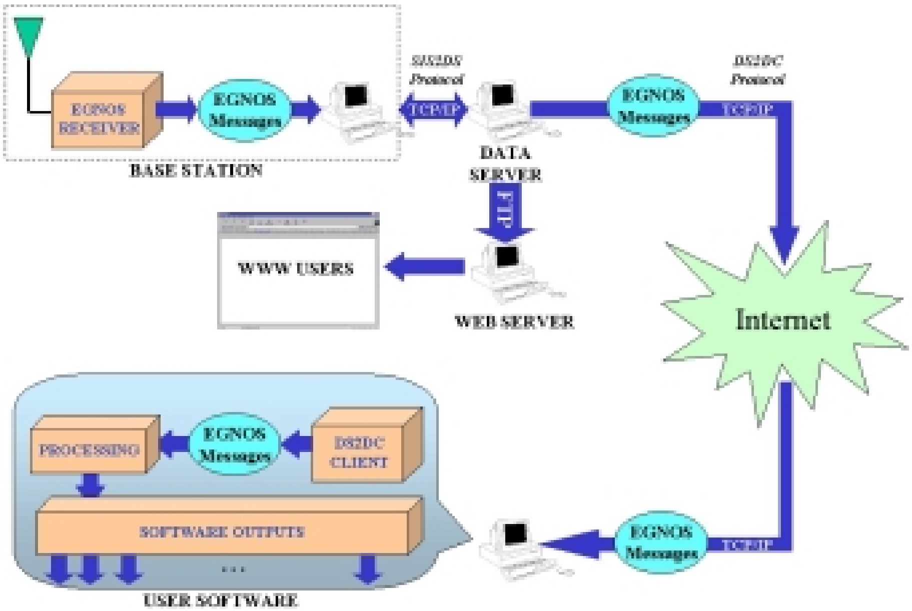

Fig. 2. Architecture of the SISNET platform

- User Application Software (UAS). A Software application that accomplishes the SISNET interface control specifications, being able to obtain the EGNOS messages in real time (1 message/s or 250 bit/s) from the DS. Moreover, the UAS can access and apply the present and future additional SISNET services. Each concrete application of the SISNET platform is defined by a specific processing stage, which provides the desired functionality to the UAS. The software can be embedded in different kind 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).

At the moment, the BS and the DS are installed on the ESA Radionavigation Laboratory in the ESTEC centre (Noordwijk, The Netherlands). The first implementation of the UAS is installed in the EGNOS Project Office (Toulouse, France), where the system is being tested and enhanced. The access to SISNET is strictly limited to the ESA development team during this phase of the project, but will be available free of charge to worldwide users, after the culmination of the project.

Base Station

The BS consists of the following components:

- An EGNOS Receiver. Currently, the BS makes use of a NovAtel Millennium card. The receiver is connected to a PC computer through a serial port.
- Receiver Control Module (RCM). A software component in contact with the EGNOS receiver. The RCM controls the receiver via the serial port, by sending standard RINEX commands. The receiver answers by sending RINEX logs to the computer each second, containing the EGNOS messages. The process is performed in real time, obtaining a message per second (i.e. 250 bit/s). The way the RCM manages the receiver is defined through an interpreted scripting language. This allows a total control of the process, and also supporting a large amount of receivers (nowadays, the most of the receivers are RINEX-compliant).
- SIS2DS Client. A client software component, implementing a SISNET-specific protocol called SIS2DS. This protocol is based on TCP/IP and is optimised for transferring the EGNOS messages to the DS in real time.

The components cited above are integrated into a software application, called Base Station Application (BSA). This software shows the EGNOS messages obtained from the receiver and the status of the communications with the DS, using a Graphical User Interface (GUI). The BSA allows connecting and disconnecting the BS from the rest of the system when needed. Furthermore, it allows running the system in simulated mode (taking the EGNOS messages from a previously logged file), which is very useful for testing purposes.

Data Server

The following list introduces the main software components of the DS:

- SIS2DS Server. The complementary communications software of the SIS2DS Client. Receives and stores the EGNOS messages in real time (1 message per second).
- FTP Transfer Module. Periodically sends the most recent EGNOS messages to a remote Web server.
- DS2DC Server. Server software implementing all the services provided to the users (mainly sending the EGNOS messages in real time). The protocol is called DS2DC, is based on TCP/IP, and is specific to the SISNET platform.
- Data Compression Module. Analyses the structure of the data to send and applies a compression algorithm. Frequently, data is compressed down to 25% of the original size. Compression algorithms allow increasing the communications efficiency between the DS and the users.

The above listed components are integrated into the SDS software. This software shows the messages received from the BS and monitors the communications with the BS and with the users of SISNET. All these features are visible to the user through a GUI, which is shown in Fig. 3.

User Application Software

The UAS is the most flexible part of SISNET. As stated above, the potential scope of SISNET applications is really extensive, and each particular application is characterised by a concrete implementation of the UAS. The process of developing SISNET-powered software applications is the following:

Fig 3. SISNET Data Server software

- Developing a SISNET-compliant client module, implementing the DS2DC protocol (see Fig. 2). That component (called DS2DC Client) shall respect all the requirements stated in the SISNET interface control document. This assures the UAS will be able to access SISNET and take benefit of its services in an appropriate way.
- Developing one or several processing stages. Those stages are implemented by the developer without any restriction, and provide the UAS with the desired functionality.
- Developing one or more user interfaces, in order to get information from the user and present the results.

Fig. 4 shows the user interface of the first UAS implementation, developed by ESA during the first half of year 2001. This software is currently being enhanced and prepared for demonstrations. The small window shown in Fig. 4 highlights one of the additional SISNET services: the broadcast of text messages to the users. The next Section introduces two examples of powerful SISNET applications conceived, designed and developed in-house by ESA.

SISNET APPLICATIONS

This Section provides two examples SISNET-powered applications, under development by ESA (using the first prototype of the SISNET platform). The first application shows how to apply the SISNET platform for real-time performance monitoring of the EGNOS system. The second example shows how the combination of SISNET, GSM and GPS receiver technologies can allow EGNOS positioning through the Internet.

Real Time Performance Monitoring

A powerful application of SISNET consists on substituting the UAS processing stage by two new components:

- The ESPADA software (the ESA internal EGNOS simulation tool) [5,6,7]
- An interface block, able to adapt the data produced by SISNET to the format used by ESPADA.

Fig. 5 depicts the resulting architecture of the system, after making those changes. Since the introduction of version 3.0, ESPADA allows analysing the EGNOS system performances using real data. Those data encapsulate the EGNOS messages and are previously recorded into a file, using an EGNOS receiver and the appropriate logging software. The actual SISNET/ESPADA integration avoids the need of logging sessions, since SISNET provides a live virtual receiver wherever a connection to the Internet is available. Indeed the present version of ESPADA is able to present performance availability maps every fifteen minutes, totally based on the EGNOS messages provided by SISNET in real time. The only requirement is a connection to the Internet.

Fig 4. ESA SISNET User Application (the first implementation of the DS2DC client and the processing stage)

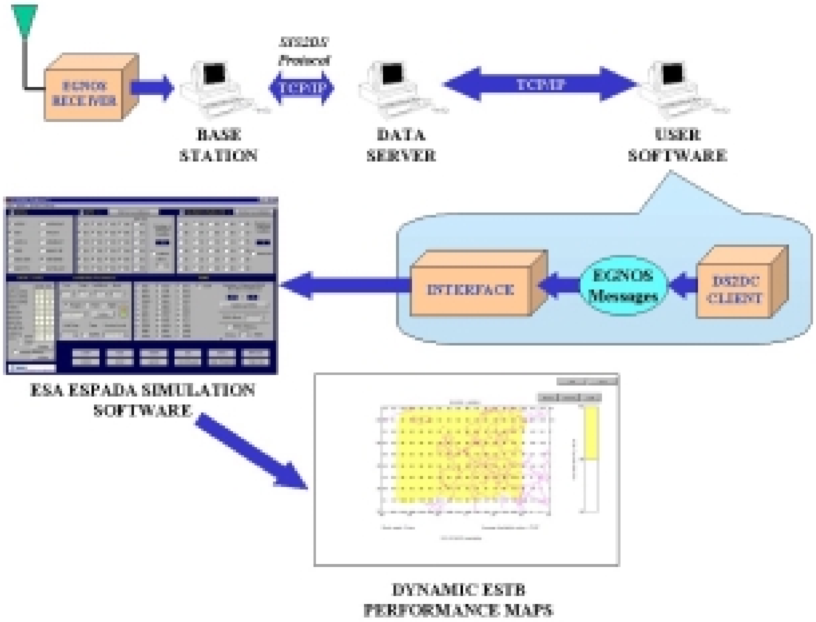

Fig 5. Application of the ESA SISNET platform: real-time performance monitoring of the EGNOS System

Positioning through the Internet

The SISNET project can grant noteworthy advantages to the GPS land-user community. A user equipped with a GPS receiver and a GSM modem can access the SISNET services, thus being able to benefit from the EGNOS augmentation signals, even under situations of GEO blocking. Fig. 6 shows the architecture of a SISNET-based solution responding to that objective. That system is becoming a reality in the context of an internal ESA project, currently under development.
In this kind of applications, the UAS is habitually embedded in a vehicle, and the access to the Internet (and hence, to SISNET) is established by means of the GSM wireless network. The processing stage of the UAS is in contact with a GPS receiver, so that pseudo-range measurements can be obtained. In parallel, the processing stage interacts with the DS2DC Client software, which provides the corrections broadcast by the EGNOS system through SISNET. With that information, a set of algorithms can compute the corrected position, notably improving the accuracy of the GPS receiver.

SUMMARY

With this paper we have introduced the ESA SISNET project, a platform that allows the access to the EGNOS Satellite Navigation services through the Internet. A first prototype of the SISNET concept has been set-up by the ***ESA GNSS-1 Project Office***. This first version uses a PC computer to implement the user equipment software, and the connection to the Internet is achieved using a LAN environment (via a proxy server). The SISNET platform has been described here in some detail, starting from a top-level view, and then focusing each of the main components of the system.

Two examples of SISNET-based applications have been described. The first example has shown how the integration of the ESA ESPADA software into the user application software allows real time performance monitoring of the EGNOS system. The second example has exposed a powerful combination of the SISNET, GPS and GSM technologies, which provides the advantages of the EGNOS augmentation services to land mobile GPS users across the Internet.

The powerful characteristics of EGNOS have been added to the powerful features of the Internet. The authors have confidence in the success of such a powerful combination, which will probably open a large amount of applications for satellite Navigation.

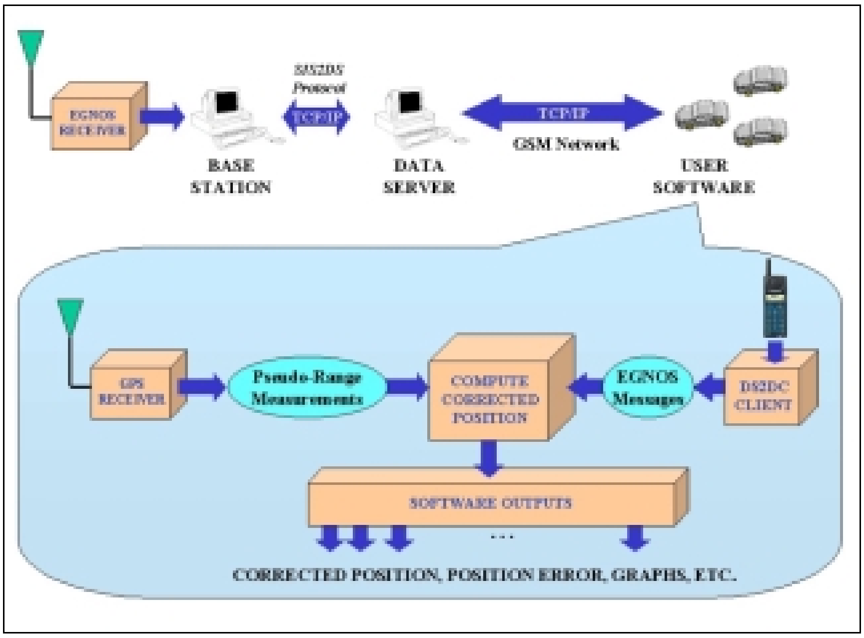

Fig 6. Application of the ESA SISNET platform: positioning through the Internet.

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