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Table of Contents

EDITORIAL PREFACE

RESEARCH ARTICLES

Client-Server Based LBS Architecture:

A Novel Positioning Module for Improved Positioning Performance

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ABSTRACT

This work presents a new efficient positioning module that operates over client-server LBS architectures. The aim of the proposed module is to fulfil the position information requirements for LBS pedestrian applications by ensuring the availability of reliable, highly accurate and precise position solutions based on GPS single frequency (L1) positioning service. The positioning module operates at both LBS architecture sides; the client (mobile device), and the server (positioning server). At the server side, the positioning module is responsible for correcting user's location information based on WADGPS corrections. In addition, at the mobile side, the positioning module is continually in charge for monitoring the integrity and available of the position solutions as well as managing the communication with the server. The integrity monitoring was based on EGNOS integrity methods. A prototype of the proposed module was developed and used in experimental trials to evaluate the efficiency of the module in terms of the achieved positioning performance. The positioning module was capable of achieving a horizontal accuracy of less than 2 meters with a 95% confidence level with integrity improvement of more than 30% from existing GPS/EGNOS services.

Keywords: Accuracy and Integrity, EGNOS, GPS, LBS, Positioning Module

INTRODUCTION

Location-Based Services (LBS) are information services providing position-related content to mobile users. LBS represent integration between position determination technologies, mobile communication and location related contents. LBS are currently being deployed for different civilian applications such as contextual advertising, user warning and alerting, transport, gaming, dynamic objects tracking and

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mobile guidance (Rapera et al., 2007; Filjar et al., 2008). Mainly LBS can be implemented in two architectures, one as stand-alone, where the mobile unit is equipped with on board positioning devices, maps and geographical information, which are used to provide the user with required service locally. The second architecture is described as client-server based, in which services are remotely delivered to users either on demand or consecutive dependent on the application type being implemented.

LBS application's performance mainly depends on the capability and reliability of its components. This includes the positioning technology performance in terms of the achieved service availability, position accuracy and integrity. Also, the mobile network's latency, available bandwidth, and data rates along with the mobile handsets memory capacity and processing power plays an important role in delivering the required service to the user. LBS applications require up-to-date and accurate location related information, such as maps, images, voice and video records, transport and weather updates, and so forth (Tsalgatidou et al., 2003; Aredo et al., 2003).

Generally, LBS applications deliver sensitive information services related to the user's location. Therefore, a critical aspect of LBS implementation is identifying a suitable positioning technology that is capable of efficiently determining where (user accurate location) and when the required services are delivered. Currently, there are several positioning technologies available for navigation purposes in different LBS applications. However, this work focuses on the Global Positioning System (GPS) as the most widely deployed positioning technology.

POSITIONING TECHNOLOGIES BACKGROUND

Generally, the positioning technologies are divided into two major categories. The first one is described as network-based which involves different types of implementations such as mobile network positioning, in which mobile signals and the network infrastructure are used to locate the mobile device utilising several methods such as Angle of Arrival (AoA), Time of Arrival (ToA) and Enhanced Observed Time Difference (E-OTD). Also, this category includes wireless local network (Wi-Fi) and Radio Frequency Identification (RFID) based positioning, these methods are mainly used for position determination in local scales and indoor environments (Esmond, 2007). However, the network based positioning techniques are still not widely implemented as stand alone solutions because of its accuracy limitations. In addition, network operators still are not considering that LBS applications are typically to be utilised by all mobile phone users.

The second main category is known as satellite-based positioning, in which satellite signals are received by handheld receivers and used to position the mobile device based on a triangulation process of three or more different signals. This technology is known as the Global Navigation Satellite Systems (GNSS) such as GPS which has been widely utilised for a variety of air, land and sea applications. GPS is considered as the cornerstone of positioning in LBS applications because of its simplicity of use, inexpensive implementation, and global availability (Filjar, 2003). However, the positioning performance provided by a single frequency GPS receiver has proved to be insufficient for some precision and accuracy demanding applications (Kaplan & Hegarty, 2006).

The performance degradation of GPS is due to several error sources such as poor satellite geometry, satellite orbital shifting, clock errors, multipath effects, atmospheric delays and GPS receiver internal processing errors. These limitations escalate in urban environments and densely areas as there is a significant possibility for the signals to be jammed and blocked due to high obstructing buildings and difficult landscapes. A considerable attention has been carried out during the last decades trying to augment GPS positioning services among multiple signal error sources. As a result, different methods have emerged such as Differential GPS (DGPS) systems allowing GPS signal errors to be reduced or eliminated based on pseudo-range or carrier-phase differential correction procedures. DGPS systems are available with different coverage ranges, construction, augmentation data formats and data deliverability means, (Kaplan & Hegarty, 2006). Mainly, two types of DGPS systems are available. Local Area DGPS (LADGPS) systems providing limited coverage to the users based on their distance to the DGPS reference station (<100 m). Wide Area DGPS (WADGPS) systems implemented by a network of DGPS reference stations covering a wide region and being interconnected at a centralised location, this is known as multi-reference DGPS systems.

Additionally, Satellite Based Augmentation Systems (SBAS) such as the Wide Area Augmentation System (WAAS) and the European Geostationary Navigation Overlay Service (EGNOS) are considered as WADGPS systems. In SBAS, the differential data are collected from a group of interconnected monitoring and differential stations and then broadcasted to the users using GEO satellites covering a whole region such as Europe and North America. EGNOS is the European version of SBAS, developed by the European Tripartite Group; the European Space Agency (ESA), the European Commission (EC) and EUROCONTROL. EGNOS is the European's contribution to the first generation of GNSS (GNSS-1) and a primary step towards Galileo. EGNOS provides augmentation service for GPS, GLONASS and future Galileo. EGNOS infrastructure consists of four Mission Control Centres (MCC), six navigational Land Earth Stations (NLES), and thirty-one Reference Stations, described as Ranging and Integrity Monitoring Station (RIMS). Three EGNOS geostationary satellites (Inmarasat-3, IND-W, and ARTEMIS satellites) are successfully transmitting EGNOS augmentation signals consisting of orbit and clock corrections of all GPS satellites, ionospheric delays and integrity information of the GPS system (Gauthier et al., 2006)

In the same concern, the increase of Internet capability and accessibility has made it possible to use the network as an alternative method for transmitting augmentation data for real time GPS users. The Signal in Space via the Internet (SISNet) was developed to allow access to the wide area differential corrections and integrity information obtained from EGNOS in the Radio Technical Commission for Aeronautics (RTCA) format, (Torán-Martí et al., 2002). SISNet data is accessible free of charge to internet users and only requires valid privileges from the European Space Agency (ESA). Additionally, the Network Transport of RTCM via Internet Protocol (Ntrip) was introduced for broadcasting GPS differential corrections in Radio Technical Commission for Maritime (RTCM SC-104) format over the internet to authorised users (Dammalage et al., 2006). This technology is currently being utilised by several national and regional DGPS networks, such as the Ordnance Survey GPS Network (OS Net) in UK. OS Net is a network of several DGPS reference stations providing real time L1 DGPS and Real Time Kinematics (RTK) correction for users in Great Britain (Ackroyd & Cruddace, 2006). The OS Net DGPS corrections can be received in real time from the OS Net Ntirp caster via the Internet, radio or mobile channels.

In this work, the concept of using the internet network as a source of GPS augmentation data is utilised by the proposed positioning module at the server side (positioning server). This includes the reception of EGNOS data from SISNet (GPS/EGNOS-SISNet solution) and networked-DGPS corrections from the OS Net Ntrip caster (GPS/DGPS-Ntrip solution). The use of these two solutions has offered a guaranteed availability of correction data which is required to augment the roving user's GPS measurements for improved positioning performance. This has also reduced the amount of processing power and memory space required to perform the correction calculations at the mobile device. The concept of EGNOS integrity monitoring was also utilised and implemented at the mobile device, to identify situations were additional GPS assisted data and accurate position solutions are needed from the positioning server. The following section describes details of EGNOS integrity calculations.

EGNOS INTEGRITY MONITORING

Utilising the EGNOS service allows the user's receiver to get the following types of information (RTCA, 2001):

- ➢ Satellite information such as the ephemeris data of the tracked satellites and associated corrections.
- ➢ Ranging information, including GPS satellite clock and ephemeris errors corrections, and ionospheric corrections.
- ➢ Measurement integrity information, provided in the form of variances related to two types of error corrections; the UDRE for the satellite clock corrections and ephemeris, as well as the variance for Grid Ionospheric Vertical Error (GIVE).

This information is carried by the following EGNOS message types:

1. Message types 2-5 contain the fast corrections in pseudo-ranges and UDRE values for each satellite.
2. Message type 6 might be transmitted containing all UDRE's in case of a system alarm.
3. Message type 7 specifies the fast correction degradation factor indicator for computing the degradation of fast corrections.
4. Message type 18 and 26 contain ionospheric correction information and the corresponding GIVE values.
5. Message type 24 is a mixed fast and slow correction message.
6. Message type 25 provides error estimates for slow varying satellite ephemeris and clock errors.

The GPS receiver combines satellite and user geometry information with EGNOS corrected pseudo ranges to compute the user's position. Moreover, the use of EGNOS integrity data allows the calculation of useful integrity factors, such as the Horizontal Protection Level (HPL_{SBAS}) and Vertical Protection Level (VPL_{SBAS}) corresponding to the horizontal and vertical position solutions respectively (RTCA, 2001; Walter, 2003). Every time a protection level is calculated it should be compared with its identified Position Error (PE) upper bound, known as the Alert Level (AL). The Misleading Information (MI) situations or the integrity failure events are determined based on samples with $HPL_{SBAS} > HAL$ and $VPL_{SBAS} > VAL$ for the horizontal and vertical position solutions, where VPL and HAL are the vertical and horizontal alert levels.

An integrity failure event can be caused by several reasons such as equipment breakdown and measurement noise. EGNOS integrity monitoring method is based on the mathematical expressions which were originally developed for aviation navigation purposes (RTCA, 2001). However, this concept can be modified for the needs of pedestrian's and vehicle navigation with respect to the integrity multipliers (K-factors) that should be adjusted according to the application requirements (Abwerzger et al., 2004). EGNOS integrity monitoring is based on the estimation of the variances in pseudo-range measurements for all tracked satellites; this can be presented by (RTCA, 2001):

$$\sigma_i^2 = \sigma_{i,UIRE}^2 + \sigma_{i,tropo}^2 + \sigma_{i,flt}^2 + \sigma_{air}^2 \tag{1}$$

Where, (σ_i^2) is the total error variance in the pseudo-range measurements and i is the satellite number:

- ➢ The error variance ($\sigma_{i,UIRE}^2$) indicates the residual User Ionospheric Range

Error (UIRE) for each pseudo range after applying the ionespheric corrections. This error can be derived from the variance (σ^2_{GIVE}) which describes the GIVE received values for an ionospheric correction module.

- The error variance ($\sigma^2_{i,tropo}$) indicates the residual tropospheric error in each pseudo range.
- The error variance ($\sigma^2_{i,flt}$) is the error caused by the ambiguity in slow and fast corrections. This parameter can be determined from the variance ($\sigma^2_{i,UDRE}$) which describes the UDRE for each pseudo range correction after applying fast and long term correction messages.
- The estimation of pseudo range error caused by the receiver's noise and multi-path effects is indicated by (σ^2_{air}), this can be derived from the following equation:

$$\sigma^2_{air} = \sigma^2_{i,noise} + \sigma^2_{i,multipath} + \sigma^2_{i,div} \tag{2}$$

Where (σ_{div}) estimates the errors caused by the receiver filter causing an ionospheric divergence.

Accordingly, σ^2_i refers to the distribution that over bounds the real range error. Therefore, the variance in the position domain is a combination of σ^2_i and is also represented by a zero-mean nominalization:

The variance in the horizontal position domain is computed as follows:

$$\sigma^2_H position = \sum_{i=0}^{n} S^2_{H,i}\,\sigma^2_i \tag{3}$$

The variance in the vertical position domain is computed as follows:

$$\sigma^2_V position = \sum_{i=0}^{n} S^2_{V,i}\,\sigma^2_i , \tag{4}$$

$S_{H,i}$ and $S_{V,i}$ are geometrical parameters. Afterwards, the horizontal and vertical protection levels (HPL_{SBAS} and VPL_{SBAS}) are obtained from the following two equations:

$$HPL_{SBAS} = K_{H.Ped}\sqrt{\sigma^2_H position} \tag{5}$$

$$VPL_{SBAS} = K_{V.Ped}\sqrt{\sigma^2_V position} \tag{6}$$

Where, $K_{H.Ped}$ and $K_{V.Ped}$ are the constant integrity multiplier factors required for pedestrian applications. As specified by Abwerzger et al. (2004), these multipliers can have the values of 4.6 and 4.2 respectively, for a probability (integrity risk) that is less than or equal to (2.5×10^{-4}/60 seconds).

CLIENT-SERVER LBS ARCHITECTURE

A client-server based LBS architecture is presented in Figure 1. A new component was added at the server side, described as the positioning server which maintains an internet connection with SISNet data server and with OS NET Ntrip caster ensuring high GPS augmentation data availability. Also, a GPS receiver mounted in a good satellite view can be connected to the server side and used to continuously download up-to-date navigation data from most satellites. In addition, application and data content servers can also be connected with the positioning server through a middleware component forming a complete LBS system. This scenario is more likely to take place if services are delivered remotely to the user (i.e., Blind and disabled guidance services, advertisements, etc.). Concurrently, the mobile or user side consist of a mobile device (e.g., PDA) with built in or attached single frequency GPS receiver with DGPS capability (e.g., EGNOS).

A bidirectional mobile/wireless communication link is utilised between the mobile device and the positioning server. The capability of current mobile communications for such configurations along with the server side performance limitations was analysed and investigated thoroughly in (Hunait et al., 2004; Alhajri et al., 2008; Almasri et al., 2009). As mentioned earlier, the mobile device transmits its GPS data (raw and/or coordinate measurements) in case of an integrity failure to the positioning server, which is responsible for efficient position correction and calculation. This process is described within the proposed positioning module as explained in the following sections.

PROPOSED POSITIONING MODULE

A new positioning module is proposed to operate in a multithread hybrid approach for achieving highly accurate GPS position solutions. The proposed system is based on the positioning information acquired by the user's mobile device and computed at the positioning server. One of the most important elements at both sides is the hardware interface that is responsible for configuring and communicating with all hardware devices to acquire and transmit the required data types. Figure 2, presents a flowchart of the mobile device functional approach.

At the mobile device, raw data (code pseudo-range measurements) or standard position coordinate fixes (NMEA-GGA data) are acquired, filtered and then stored based on EGNOS fast corrections update time interval (6 seconds). This data along with EGNOS integrity information are passed to the integrity monitoring function. Afterwards, HPL_{SBAS} values for each position solution are then computed and compared to the specified position error bounds to detect any integrity failure situation. In case of any integrity failure or EGNOS data unavailability user's measurements and the associated time stamps are transmitted to the server. At the dedicated positioning server the hardware interface con-

Figure 1. Mobile-server LBS architecture

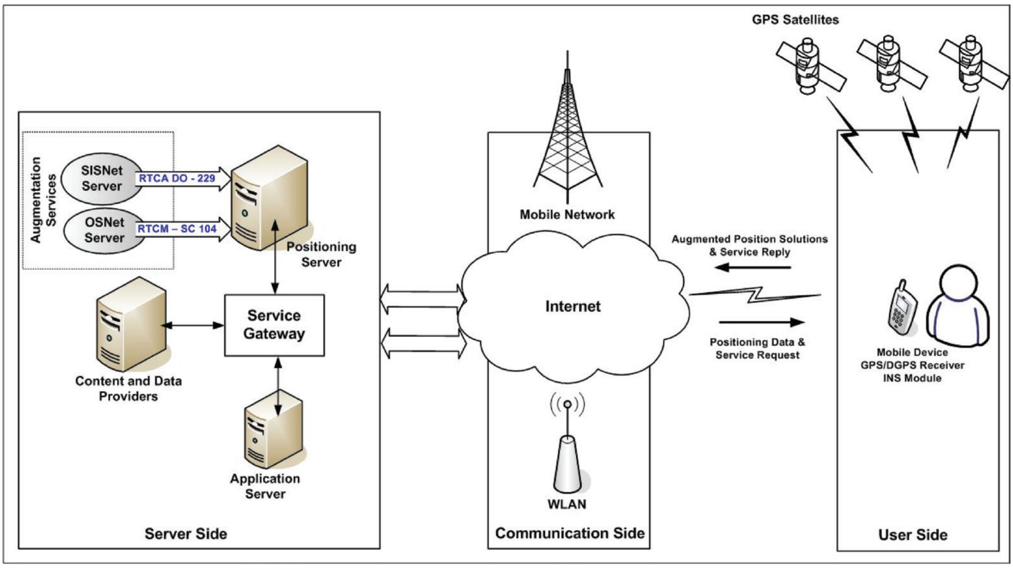
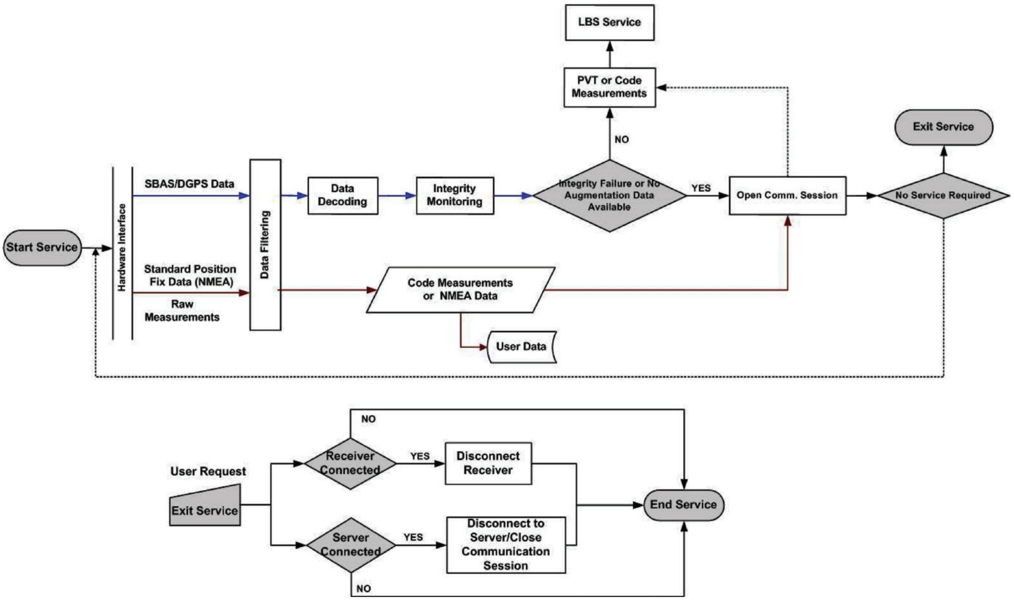


Figure 2. Mobile device flow chart diagram



tinuously downloads the navigation message for each satellite along with correction information from both the SISNET and OS Net. The positioning server functional approach is shown in Figure 3 below.

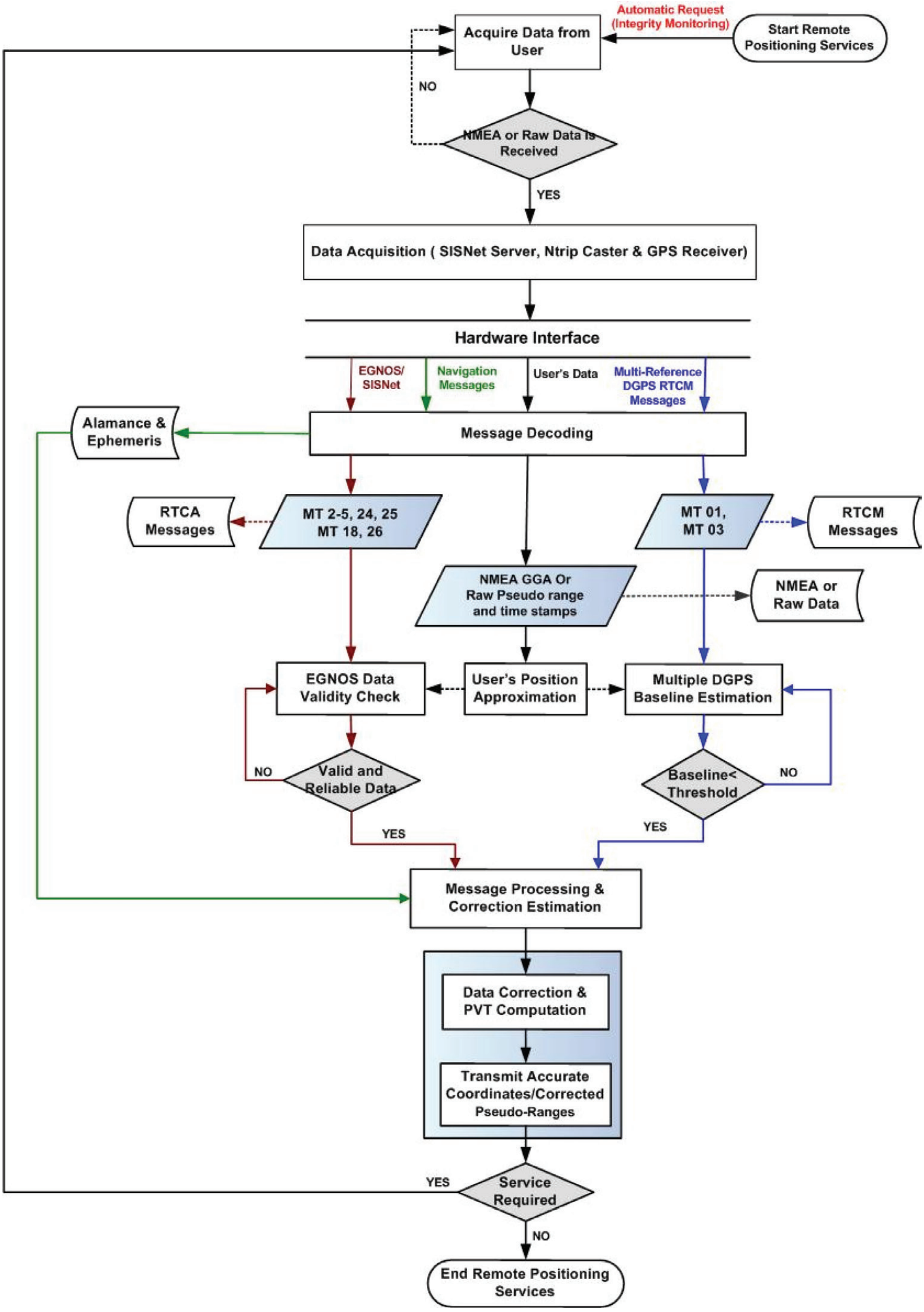
The navigation messages are downloaded in order to obtain the satellite vehicles (SVs) clock parameters, ionospheric delay coefficients and the ephemeris parameters for satellites positions computation. This information is stored in a local memory buffer at the server. EGNOS correction messages are received from the SISNet server and then decoded into the Minimum Operational Performance Standard (MOPS) format based on the 6 bits type identifier (IODE). The required EGNOS Message Types (MT 2-5, 18, 24, 25, 26) are also periodically stored at the server. Additionally, RTCM data streams received from the OS NET caster are decoded (MT 01 and MT 03) saved into a different memory buffer. Data stored in all memory buffers at the positioning server are pulled based on GPS time of the user's raw measurements.

The raw pseudo-ranges received from the mobile device are correlated with data stored in the local buffers to obtain an initial position of the user and a rough estimated time bias. Afterwards, EGNOS messages validity constrains and OS NET reference stations baseline estimation is performed to use the applicable and valid augmentation services for correcting the raw pseudo-ranges. The correction process is based on the differential correction software approaches presented in (ICD-GPS, 2000). Afterwards, user measurement errors should be removed; hence an accurate and precise user Position, Velocity and Time (PVT) is computed and sent to the user. This process will repeat until the user ends the service or when the mobile device is not experiencing any integrity failure event.

PRELIMINARY FIELD EXPERIMENTS

Field observations were carried out in order verify the efficiency of the proposed positioning module in improving the accuracy and reliability of position solutions obtained from a single frequency GPS receiver with EGNOS

Figure 3. Positioning server flow chart diagram



capability. The evaluation process was based on comparing the positioning performance (horizontal accuracy and integrity levels) achieved within 95% confidence level at the mobile device using the GPS/EGNOS receiver, along with the performance achieved at the positioning server using the GPS/EGNOS-SISNet and GPS/DGPS-Ntrip solutions.

Experimental Setup

Several MATLAB M-functions were developed to implement the functionalities of the proposed positioning module. A prototype of the mobile device was used during the experiments consisting of the following:

- Fujitsu Siemens Laptop, Pentium M, 2 GHz, 2GB RAM.
- High Speed Downlink Packet Access (HSDPA) data card.
- U-Blox LEA-4T GPS sensor for raw GPS measurements and LEA-4H with SBAS/EGNOS functionality.

The positioning server was compiled of the following:

- Intel Dual Xeon computer, 3.2 GHz, 12 MB cache, 1600 FSB and 8GM.
- GPS receiver, the antenna was mounted on the roof of Tower A at Brunel University.
- The essential software components running at the server was:
  1. SISNet User Application Software (UAS) version 3.1.
  2. GNSS internet radio version 1.4.11, maintaining the Ntrip connection with OS NET caster.
  3. U-BLOX U-centre for personal computers used as GPS evaluation software.

Measurement Methodology

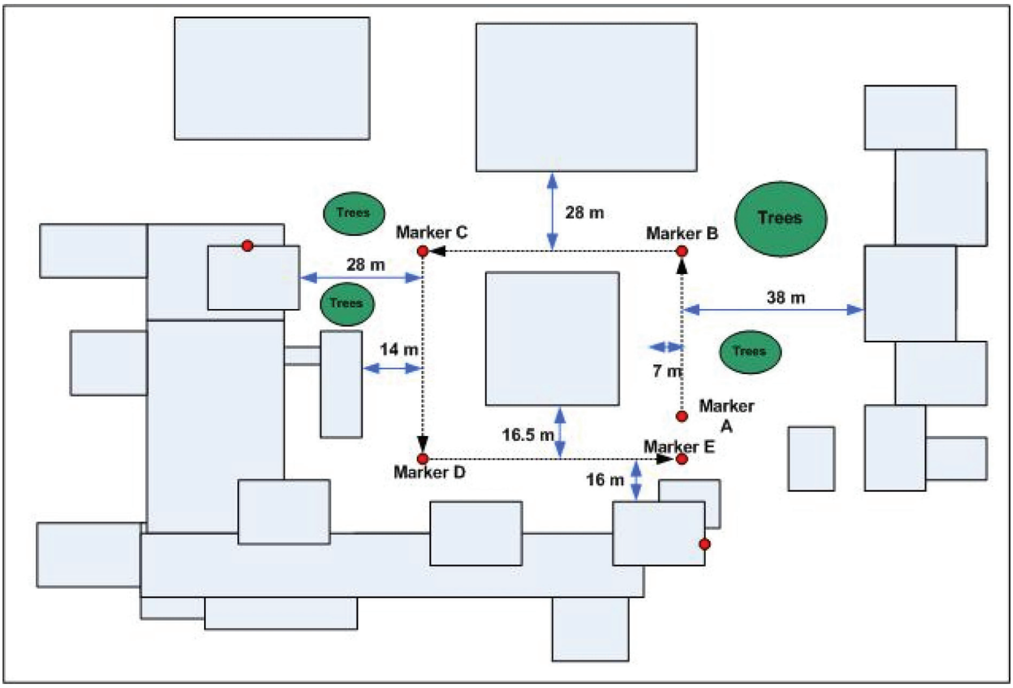
A pedestrian's trajectory at Brunel University, Uxbridge campus in the UK, was chosen to conduct dynamic field GPS measurements. The testing route was carefully selected to simulate a typical urban area with parts where signals from the satellites are very likely to be blocked. Five marker points (Point-A, B, C, D and E) were identified along this route. The marker points were extensively surveyed over several days with centimetre accuracy in order to verify the positioning accuracy along the route. Table 1, presents the marker points surveyed horizontal location in the European Terrestrial Reference System 1989 (ETRS89) coordinates system, with a UTM zone equals 30 (Ordnance Survey, 2008). Figure 4, illustrates the testing route along with the structure surrounding the five marker points.

According to the marker points coordinates, the main OS NET reference station (mount-point) being used to receive DGPS corrections at the server was (TEDD), in which the baseline from the testing route was less than 15 KM. Additionally, in order to account for different constellations of GPS satellites, the field observations were repeated for twelve times at different periods of the day. Each observation

Table 1. Marker points coordinates

Marker Point	Easting (m)	Northing (m)
Point-A	675281.7	5711978.8
Point-B	675281.7	5712030
Point-C	675228	5712030
Point-D	675228	5711958
Point-E	675281.6	5711958

Figure 4. Testing route at Brunel University campus



session lasted for 50 minutes, from the beginning till the end of the route. During each session, at least 100 position solutions were recorder at each marker point in a rate of 6 seconds per sample. The size of each position solution is dependent on the GPS receiver output packet length. Normally the size of each packet containing a GPS epoch is around 255 bytes. The raw GPS measurements were logged at each point along the route using the LEA-4T GPS sensor. The positioning performance along each marker point was assessed in terms of the position accuracy and integrity. The accuracy was measured using 2DRMS (Distance Root Mean Square) statistical method and the integrity computation followed the equations presented previously.

Results Analysis and Discussion

The results described in this section are related to a measurement trial that took place between 12:00pm and 12:50pm. The scattering of the residual errors in the position samples computed at the mobile device, using the existing GPS/EGNOS service, for points A, B, C, D and E are described in Figure 5. The x-axis presents the easting error in meters (m) and the y-axis is the northing error in meters (m). Additionally, the corresponding HPL_{SBAS} values computed at each marker point for all position samples are shown in Figures 6, in which the x-axis presents the position sample number and the y-axis is the HPL_{SBAS} values in meter.

The standard deviations of the easting and northing position components errors obtained using the mobile device at points A, B, C, D and E were (0.95 m, 1.1 m), (0.92 m, 0.95 m), (1.3 m, 1.4 m), (1.4 m, 1.6 m) and (0.85 m, 1.1 m), respectively. The horizontal position accuracy at a 95% confidence level achieved at the same marker points was 2.9 m, 2.6 m, 3.8 m, 4.3 m and 2.8 m. Additionally, the corresponding average of HPL_{SBAS} values at each marker point was 9.4 m, 9.2 m, 10.4 m, 11.1 m

Figure 5. Easting and northing position samples residual errors at marker points (A, B, C, D, and E) obtained by the mobile device during the observation session (12:00pm till 12:50pm)

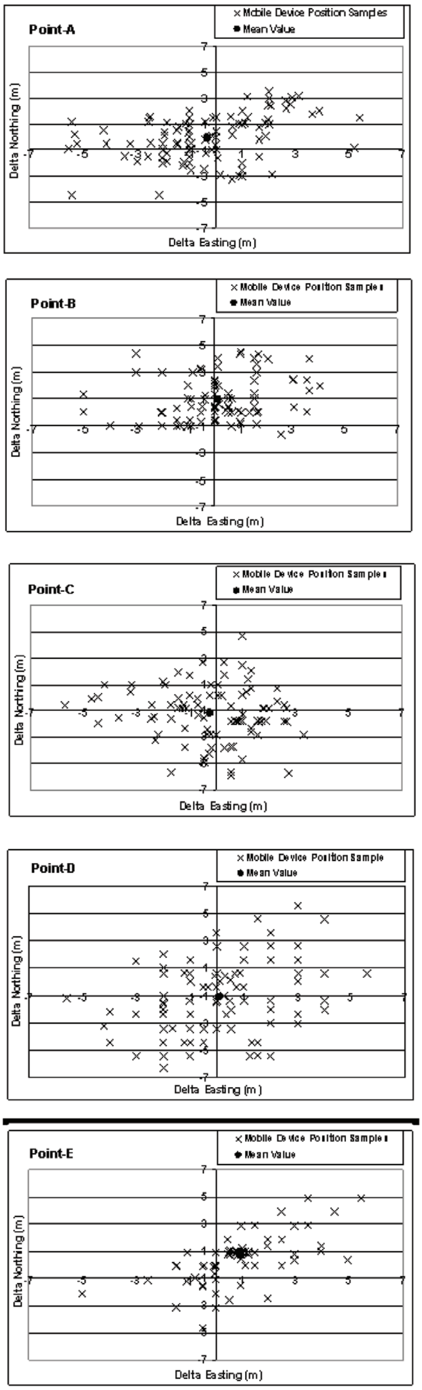
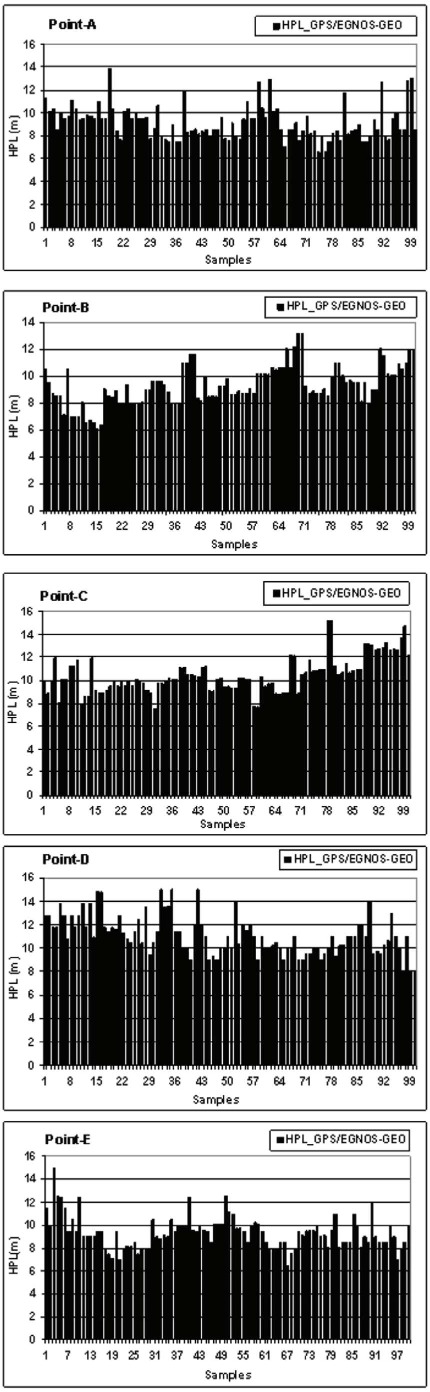


Figure 6. Corresponding HPL_{SBAS} *values computed for each position sample at marker points (A, B, C, D, and E) during the observation session (12:00pm till 12:50pm)*



and 9.3 m. Furthermore, a coordinate trace from the measured position samples representing the pedestrian's measured route was obtained with a horizontal accuracy average of 3.46 m at a 95% confidence level. The low horizontal accuracy levels achieved at points C and D were due to EGNOS signal blockage from two surrounding buildings (4 storey "Howel" and 5 storey "Tower B") near to the points.

Conversely, the raw measurements collected at each marker point during the same time interval (12:00-12:50pm) were processed at the server side using the proposed module. These measurements were corrected using the GPS/EGNOS-SISNet and GPS/DGPS-Ntrip solutions in the basis of 6 seconds time interval. Accordingly, the results presenting the positioning performance achieved from the proposed module are described in Figure 7 and Figure 8. The scattering of the residual errors in the position samples computed at the positioning server for points A, B, C, D and E are described in Figure 7. Additionally, Figure 8 shows the probability distributions of all easting and northing errors at each marker point. The easting and northing errors distributions at the positioning server are presented by the black continues lines and the black dashed lines, respectively. Corresponding easting and northing errors distributions at the mobile device are presented in the gray continuous lines and gray dashed lines respectively.

As shown in Figure 8, the residual error distributions obtained at the server side (black lines), are always contained within low error margins and within high probability, comparing to the error distributions of the augmented stand-alone (GPS/EGNOS) measurements (gray lines) obtained at the mobile device. This implies that the positioning server is capable of providing improved position solutions using the proposed module. The standard deviation of the residual easting and northing components errors and obtained at the positioning server at all marker points were: (0.59 m, 0.64 m), (0.58 m, 0.63 m) (0.66 m, 0.75 m) (0.61 m, 0.72 m) and (0.54 m, 0.62 m) respectively. Accordingly, the achieved horizontal accuracy with 95% probability was: 1.7 m, 1.7 m 2.0 m, 1.9 m, and 1.6 m. For the same time interval, a coordinate trace representing the pedestrian's computed route at the positioning server was obtained with a horizontal accuracy of 1.7 with 95% confidence level. A numerical analysis of the overall filed observations conducted during the 12 testing trials is presented in Table 2.

As shown in Table 2, the positioning server was capable of computing highly accurate position samples with a horizontal accuracy average of less than two meters (1.7 m) (1.5 m) using the GPS/EGNOS-SISNet and GPS/DGPS-Ntrip solutions. In addition, the availability of EGNOS data at the positioning server has also allowed computing EGNSO integrity parameters. The number of samples within an integrity hazardous event ($HPL_{SBAS} > HAL$) during the whole period was less at the positioning server comparing to the mobile device. This was due to EGNOS signals blockage and outage at the mobile side, which has increased the magnitude of the computed horizontal protection levels. Accordingly, it was verified that the positioning server was able to compute user's coordinates with improved integrity and accuracy levels (< 2 meters) even in scenarios where the augmentation service at the mobile side are blocked or during an integrity failure event. This confirms the efficiency of the proposed positioning model and its importance for LBS applications.

CONCLUSION AND FUTURE WORK

A new hybrid positioning module increasing GPS positioning reliability and accuracy for the intention of client-server based LBS applications was introduced. The new module included new functional approaches to switch the mobile device from standalone position determination mode, using a GPS receiver with

Figure 7. Easting and northing position samples errors for marker points (A, B, C, D, and E) computed at the server during the observation session (12:00pm till 12:50pm)

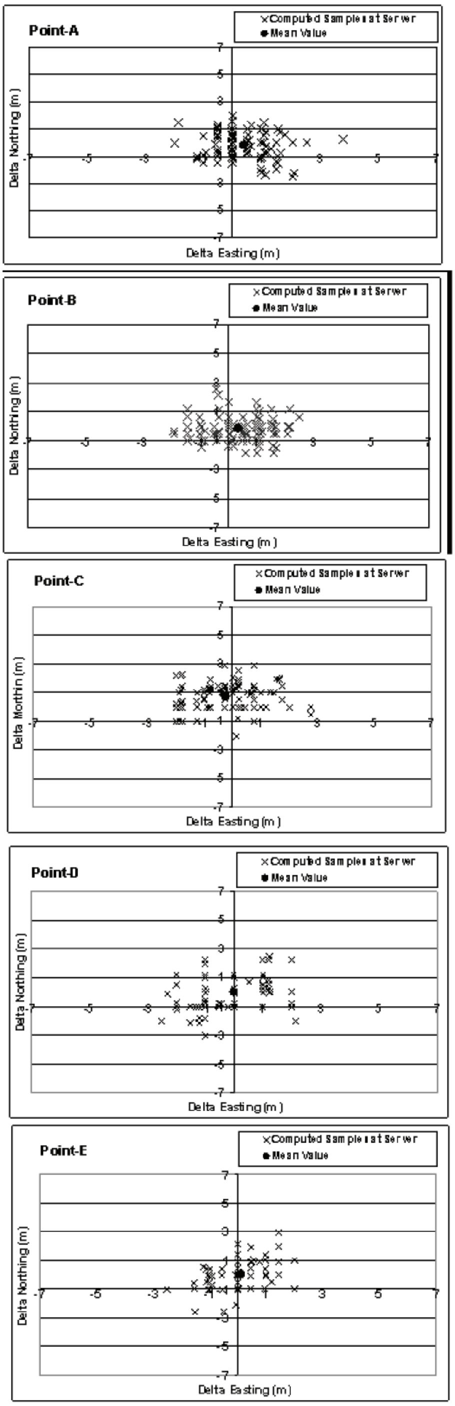


Figure 8. Easting and northing cumulative probability distribution computed at the server and at the mobile device for marker points (A, B, C, D, and E) during the observation session (12:00pm till 12:50pm)

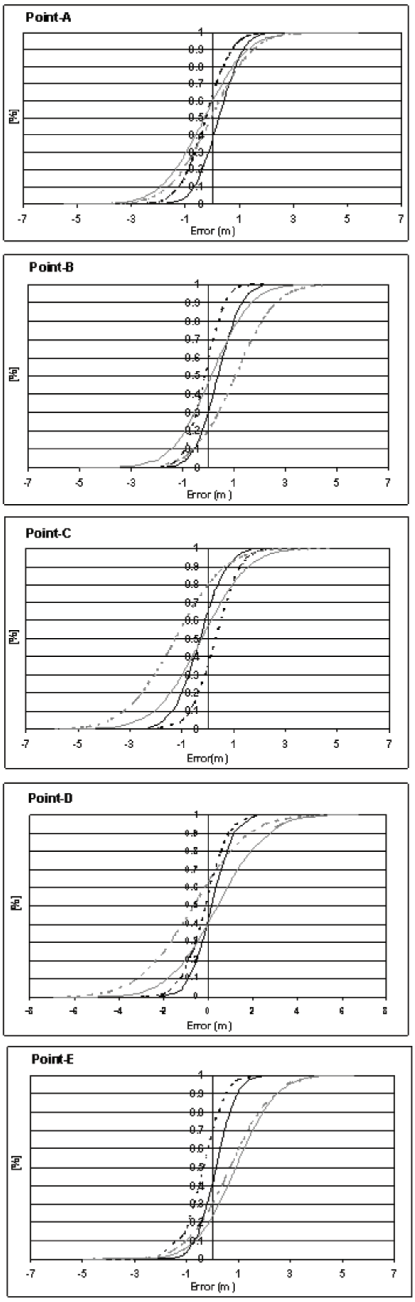


Table 2. Experimental analysis for all testing sessions

Parameter	**Positioning Server** (GPS/ EGNOS-SISNet)	**Positioning Server** (GPS/DGPS-Ntrip)	**Mobile Device** (GPS/EGNOS**)**
Number of samples	5988 (99.8%)	5988 (99.8%)	6000 (100%)
Sample frequency	6 sec/sample	6 sec/sample	6 sec/sample
Average of horizontal accuracy (95%)	1.5	1.7	3.5
Samples within the HMI zone (HAL=10 m)	360	360	840
GPS signals availability	98.5%	95.5%	85%
Augmentation data availability	>99.8% (SISNet Server)	>99.8% (OS NET Server)	>85% (Geo Satellites)

SBAS capability, to server-based mode utilising a dedicated positioning server, in case of data integrity failure at the mobile device. This new module provides more accurate position solutions comparing to the standalone GPS receivers, and maintains an improved level of positioning integrity regardless of user's location. The experimental evaluation results have indicated that the positioning server was able to take over the link in data integrity failure events. Also, the results have shown that the positioning module can successfully correct the raw data and compute accurate coordinates at the positioning server with a horizontal accuracy of less than 2 meters within a 95% confidence level.

In the future, the use of Integrated Navigation Sensors (INS) will be included within the scope of the proposed module. An adaptive multisensory fusion method based on Kalman filtering approaches will be developed in order to fuse GPS data with navigation information reported from the interior sensors. The central task of GPS and INS integration is to benefit from the complementary characteristics of both systems in order to provide long term stable positioning accuracy solution in different navigation environments. Accordingly, the future module will aim to significantly aid the positioning performance in most navigation conditions with a special attention to in-door environments.

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