Evaluation of a Real Time DGPS Data Server

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15th January 2004

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Abstract

The goal of the this paper is to show that the DGPS data Internet service we designed and developed provides *campus*-wide real time access to Differential GPS (DGPS) data and, thus, supports precise outdoor navigation.
First we describe the developed distributed system in terms of architecture (a three tier client/server application), services provided (real time DGPS data transportation from remote DGPS sources and *campus*-wide data dissemination) and transmission modes implemented (raw and frame mode over TCP and UDP). Then we present and discuss the results obtained and, finally, we draw some conclusions.
Keywords: *Differential GPS, precise positioning, navigation, distributed systems.*

1 Introduction

Global Navigation Satellite Systems (GNSSs), such as the North-American NAVSTAR Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS), provide continuous, worldwide, all weather absolute positioning services to end-users. However, these standard absolute positioning services do not exhibit, *per se*, sufficient accuracy to support precise outdoor navigation. To overcome this inconvenience, a differential positioning methodology, built upon existing GNSSs, was developed in the nineties. The resulting differential systems grant increased positioning accuracy but, unlike GNSSs, provide a local service that is not necessarily public.
In order to increase the real time GPS-based positioning accuracy of the outdoor navigation tasks carried out in our *campus*, we decided to provide *campus*-wide access to adequate real time differential data [6]. To achieve this goal, we designed

and implemented a distributed application responsible for establishing Internet data links between remote differential data sources and the *campus* and for providing a *campus*-wide differential data dissemination service.
This paper describes this project and presents the results obtained. Section 1 provides the motivation and goal. Section 2 introduces the concept of real time DGPS systems. Section 3 describes the developed application. Section 4 presents the results and, finally, section 5 draws some conclusions.

2 Real Time Differential Positioning

A real time Differential Global Positioning System (DGPS) is, by definition, a relative positioning methodology supported by the continuous computation and broadcast of the range errors of the GPS satellites in view. This methodology relies on a group of terrestrial reference stations, called DGPS base or reference stations, located at precisely geo-referenced locations and equipped with high quality GPS receivers. The computed corrections are to be applied, within a given time-window, to the measurements of rovers situated in the vicinity – the applicability and accuracy of the corrections deteriorate as the distance between station and rover increase (Figure 2.1).

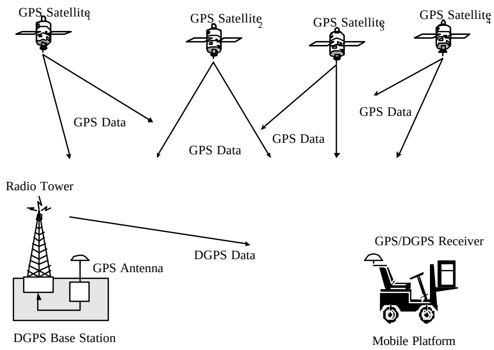

Figure 2.1 – Components of a DGPS System.

There are two real time differential positioning methods – the code phase and the carrier phase methodologies. Whereas standard code phase measurements – also referred as pseudorange corrections – provide a relative accuracy of a few meters (< 5 m), carrier phase measurements provide a relative accuracy of a few centimetres. Carrier phase and high accuracy code phase corrections are usually used in real time kinematic (RTK) applications.

2.1 DGPS via Internet

The idea of disseminating DGPS corrections over the Internet in real time for precise differential positioning and navigation purposes was also investigated by others. In 1999, W. Rupprecht [5] developed a DGPS data server called DGPSIP that disseminates DGPS data received through a radio interface at an average of 284 b/s, i.e., sends out a packet roughly every second with 35 bytes of data and 40 bytes of IP header. The DGPSIP is a multithreaded server, supports up to 64 concurrent connections and also transmits multicast UDP corrections. In 2002, the European Reference Frame (EUREF), which is a Sub-Commission of the International Association of Geodesy, decided to set up and maintain a differential GNSS infrastructure (DGNSS) on the Internet using stations of its European GPS/GLONASS Permanent Network (EPN) to disseminate RTCM corrections over the Internet in real time. To grant access to the EPN DGNSS trial servers, EUREF provides, since 2002, a free client software that transmits the standard RTCM protocol over TCP [3] and, more recently, an HTTP-based application called Networked Transport of RTCM via Internet Protocol (NTRIP) [7].

2.2 RTCM Protocol

Reference stations generate differential correction messages according to the Radio Technical Commission for Maritime Services Special Committee (RTCM) N. 104 protocol [2]. The RTCM messages are made of standard International Reference Alphabet (IRA) bytes (8-bit length) where the two most significant bits are set to space and mark (01) and the remaining 6 bits constitute the so-called RTCM byte (Figure 2.2). The messages are composed of 30-bit length (five RTCM bytes) blocks called RTCM words (Figure 2.2), holding 24 data bits and 6 parity bits.

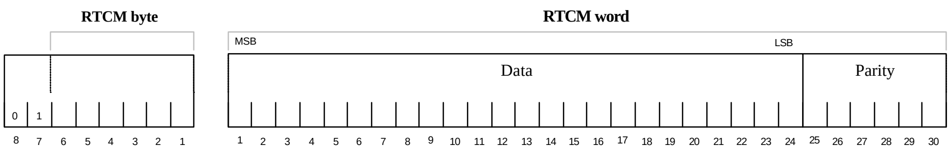

Figure 2.2 – (a) RTCM Byte; (b) RTCM Word.

A RTCM message is made of a mandatory header followed by a body of data of variable word length. The header (Figure 2.3) is two words long and includes a fixed preamble (01100110) and several other fields.

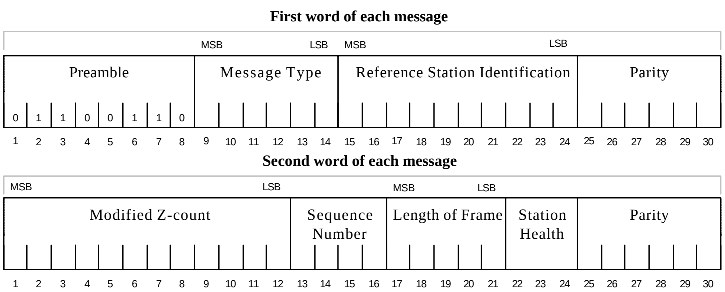

Figure 2.3 – RTCM Header.

These fields accommodate the message type (6 bits), reference station ID (10 bits), parity (6 bits), modified Z-count (13 bits), sequence number (3 bits), length of frame (5 bits), station health (3 bits) and a last parity field (6 bits). The modified Z-count represents the reference time – the "age" parameter – for the differential data messages. The sequence number varies between 0 and 7 and increments by one every time a new message header is generated. The length of frame indicates the length of the message in RTCM words. The parity bits are used for two purposes: to encode the 24 data bits of the following word and to hold the parity value of the current word data bits. The algorithm used by the source to compute and by the receiver to verify the parity value of the current word and to encode/decode the data bits of the following word is the algorithm specified for the GPS signal messages (for details consult [1]).

3 Real Time *Campus*-wide DGPS Data Provider System

The developed system transports – from remote sources – and disseminates – within the ISEP *campus* – the differential data. The overall application (Figure 3.1) is a three-tier client/server distributed application. The first tier – the client tier – represents the end client applications (wireless or Intranet clients located within the *campus*). The intermediate layer – the *campus* server – fetches and disseminates the DGPS data for the end client applications. The third layer – the servers of DGPS data – acts as the data provider layer.

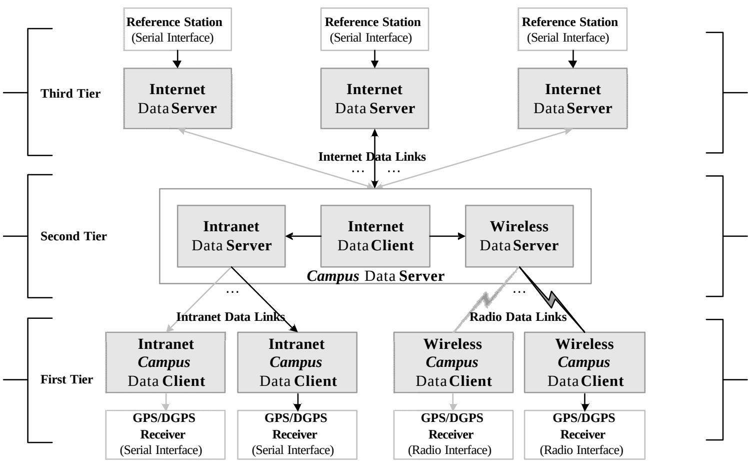

Figure 3.1 – Architecture of the System.

The first and third layers are insulated, preventing the potential congestion of the data source servers and allowing the adoption of different transport protocols between the first and second layers and between the second and third layers.

The application provides three types of data links: Intranet and wireless data links – between the first and second layers – and Internet data links – between the second and third layers and allows different transmission modes.

The Internet links are accomplished through a two-tier client/server application where the server, located at the third tier and connected to the DGPS base station, is continuously fed with DGPS data and the client, located at the intermediate tier, plays a double role: it acts as the Internet data link client and as the input module of the DGPS Data *Campus* Server. Additionally, it is capable of establishing links with multiple remote DGPS servers using the implemented data transmission modes. If multiple data sources are used, additional processing is applied.

The DGPS Data *Campus* Server, which is composed by the data input module (Internet Data Link client), the Intranet server and the wireless server, provides *campus*-wide access to real time DGPS data both via a radio beacon and via the *campus* Intranet. The wireless server module, which complies with the specifications of typical DGPS beacons (for details consult [4]), implements three tasks: (i) prepares and buffers the received DGPS messages; (ii) modulates the data onto the transmitter carrier; and (iii) broadcasts the resulting data. The Intranet server module multicasts in frame mode the valid RTCM data to the Intranet *campus* clients, which, in turn, receive and forward, via the serial interface, the data to DGPS/GPS receivers.

Figure 3.2 – GUI of the Intranet Client.

Figure 3.2 presents the Graphical User Interface (GUI) of an Intranet end-client. This GUI adopted through out the application, i.e., is common to all modules.

3.1 Data Transmission Modes

The developed application implements data links over TCP or UDP and allows multithreading. The data can be transported in frame mode or, simply, as a byte stream (raw mode). In frame mode, once a complete, error free RTCM message has been received by the DGPS remote server, a frame containing the RTCM message and other additional information is created and transmitted. In raw mode, the remote DGPS data servers transmit the RTCM byte streams without any additional processing or verification. The transmission rate of the raw byte stream is, by default, the DGPS base station output rate. However, the length of the raw mode packet size is configurable. This latter transmission mode was implemented in order to provide compatibility with other existing DGPS data client applications. When in frame mode, the remote DGPS data servers transmit frames containing whole RTCM messages. Since each data frame encapsulates a RTCM message, the frame mode depends on the continuous decoding and assembling of the serial input byte stream into valid RTCM messages. The need for this processing results from the following facts: (i) each 8-bit byte only contains 6 RTCM bits; (ii) the 6 RTCM bits arrive in reverse order (least significant bit first); (iii) every 30 bits of RTCM data holds 6 parity bits that hold the parity value of the current word data bits and are needed to decode the following word data bits. Thus, the server application has to continuously monitor the data received through the serial interface and perform diverse tasks at different levels. At the byte level, i.e., as the IRA bytes are received, it has to retrieve the RTCM byte contained in each IRA byte and reverse its content. At the word level, i.e., as the RTCM words are assembled, it must decode the data bits, verify the correctness of the word parity value, store the two least significant parity bits needed to decode the following word and search for the beginning of new messages. At the message level, i.e., once a correct message preamble has been received, the next step is to find out about the type of the message, its length and modified Z-count time of the incoming RTCM message. When a whole RTCM message is received, the data frame containing the RTCM message is created and sent over the established data link to the client.

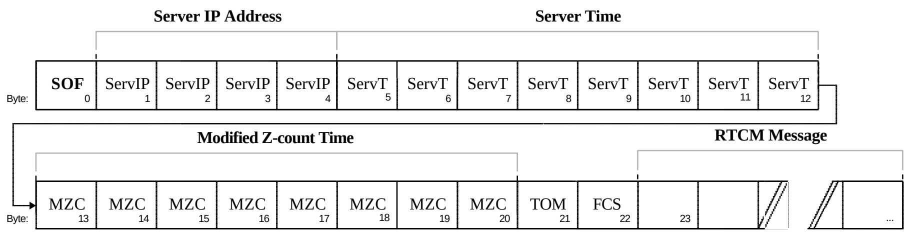

Figure 3.3 – Data Frame.

Each data frame contains a header with a start of frame (SOF) byte, four bytes containing the DGPS server IP address, eight bytes holding the server time (ServT) at the moment the frame is created, eight bytes with the RTCM message modified Z-count time (MZC), a byte specifying the type of the message (TOM), a frame check sequence (FCS) byte and, finally, the RTCM message (Figure 3.3).
As a result, the frame transmission mode allows receiving-applications on the first and second layers to immediately verify the quality of the data link transmission, as well as the age of the messages being received, and act accordingly: if a frame has transmission errors or the message contained is too old, the data frame is discarded.

By default, the *Campus* Server and the Intranet Client applications expect to receive the differential corrections in frame mode.

4 Evaluation

We identified two candidate DGPS base stations – herein called A and B – in the vicinity (10 km radius area) of our *campus*. At the time, none was broadcasting DGPS data in a format compliant with standard DGPS/GPS receivers. Currently, as a result of this project, base station B is outputting real time standard pseudorange corrections and base station A, which is already generating RTK corrections, waits for the installation of an Internet connection. Consequently, the tests conducted and presented in this paper were performed only with data from reference station B. As soon as station A is connected to the Internet, we will be able to show results using RTK corrections.

The tests were carried out using three receivers: a Magellan NAV6000 (NAV), a Garmin 176 (G176) and a Garmin 35 (G35). To compare the accuracy obtained with and without the application of the pseudorange corrections, the NAV used only GPS data and the Garmin receivers used both GPS and DGPS data. The receivers were positioned side by side and remained static through out the test.

Table 4.1 – Positioning Results.

	Elevation		Latitude		Longitude	
	Average	*s*	Average	*s*	Average	*s*
G176	128.000 m	02.141 m	N 41º10.7477’	01,224 m	W 008º36.4545’	1.175 m
G35	129.100 m	02.772 m	N 41º10.7467’	01,484 m	W 008º36.4552’	1.511 m
NAV	143.600 m	18.872 m	N 41º10.7481’	12,420 m	W 008º36.4580’	9.506 m

The 24-hour long results summarised in Table 4.1 show the receivers ordered by descending positioning accuracy. As expected, the differential positioning methodology (G176 and G35) exhibits higher accuracy than the absolute positioning technique (NAV). The ranking between the G176 and the G35 results from the fact that the G176 is a technically more advanced model.

Table 4.2 – Latency Results.

	Latency	
	Average	*s*
G176	0.053 s	0.224 s
G35	0.314 s	0.464 s

The age of the differential corrections applied by the G176 and the G35 is presented in Table 4.2. Since all corrections were applied either in the same time-slot (0 s old) or in the following time-slot (1 s old), it means that the developed application is appropriate for the transportation and dissemination of DGPS data through the Internet. The RTCM message average latency is 0.3 s (G35) and 0.1 s (G176) and the standard deviation is 0.5 s (G35) and 0.2 s (G176).

5 Conclusions

The goal of the DGPS data provider service presented in this paper is to support real time precise outdoor navigation within our *campus*. Since it is a three-tier client/server application where the first and third layers are insulated, it prevents the potential congestion of the data source servers and allows the adoption of different transport protocols between consecutive layers. As a result, *campus* data dissemination and the Internet data transportation are accomplished, by default, through multicast (UDP) and unicast (TCP), respectively. Furthermore, the data can be sent either in frame mode or in raw mode. Whereas the raw mode was kept for reasons of compatibility with existing DGPS client software applications (for example, the client software provided by [3] and [5]), the frame mode was specifically designed to allow the simultaneous connection with multiple DGPS sources and to provide an almost instantaneous mechanism of verifying the quality of the transmission and the age of the RTCM message. The inclusion of a wireless server allows the use of DGPS/GPS receivers with a wireless interface [6]. Finally, the results gathered so far show that the service provided by the overall distributed system satisfies the requirements of real time DGPS data transportation and dissemination and, thus, provides low cost support for accurate outdoor *campus* navigation. We expect to further increase our positioning accuracy as soon as we have access to differential RTK data from station A.

6 Acknowledgements

The authors wish to thank the following entities: (i) APDL; (ii) IGP; (iii) Observatório Astronómico Prof. Manuel de Barros; (iv) IDT; and (v) ISEP.

7 References

[1] "Global Positioning System, Standard Positioning Service Signal Specification", GPS Office, 2nd Edition, 1995.

[2] "RTCM Recommended Standards for Differential GNSS Service", SC N.104, Radio Technical Commission for Maritime Services, 1998.

[3] "EUREF – Real Time", http://igs.ifag.de/euref_realtime.htm, EUREF, 2002.

[4] Recommendation ITU-R M.823-2, ITU, 1997.

[5] Rupprecht, W., "DGPS corrections over the Internet", http://www.wsrcc.com/wolfgang/gps/dgps-ip.html, 2000.

[6] Soares, M. G., Malheiro, B., Restivo, F. J., "An Internet DGPS Service for Precise Outdoor Navigation", Proceedings of the 9th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'2003), Lisbon, Portugal, 2003.

[7] Weber, G., Dettmering, D., Gebhard, H., "Networked Transport of RTCM via Internet Protocol", http://igs.ifag.de/root_ftp/software/NtripPaper.pdf, 2004.