EUREF-IP for Wireless GNSS/DGNSS, Example Implementation in Madrid

Georg Weber [(1)] and Javier F. González-Matesanz [(2)]

[(1)] Bundesamt für Kartographie und Geodäsie , Richard-Strauss-Allee 11, D-60598 Frankfurt am Main, georg.weber@bkg.bund.de

[(2)]Instituto Geográfico Nacional, General Ibañez Ibero 3, 28003, Madrid, fjgmatesanz@mfom.es

Abstract

The continuously increasing bandwidth of the Internet, together with the potential of mobile IP networks like “Wireless Fidelity” (WI-FI) or “General Packet Radio Service” (GPRS), allows the real-time transmission of DGPS or RTK corrections, EGNOS data, raw data, or and other kinds of GNSS data to small and powerful devices like PDAs or Tablet PCs. From the Internet broadcasting point of view, this technology avoids a number of drawbacks of techniques such as the “Digital Audio Broadcasting” (DAB) or the “Radio Data System” (RDS). Disseminating GNSS data via Internet generates new opportunities in the field of differential positioning and navigation. Within the framework of EUREF, a concept has been developed for real-time GNSS called “Networked Transport of RTCM via Internet Protocol” (Ntrip). This paper presents results of the implementation of Ntrip using DGPS and RTK data in the Madrid area and GPRS for the communication link of a rover receiver.

1. Networked Transport of RTCM via Internet Protokol (Ntrip)

Due to the increased capacity of the Internet, applications which transfer continuous data-streams by IP-packages, such as Internet Radio, have become well-established services. Compared to these applications, the bandwidth required for the transfer of real-time GNSS data is relatively small. Because wireless or mobile Internet access is available nowadays almost everywhere, the dissemination of GNSS data via IP-streaming becomes an alternative to the usage of conventional terrestrial broadcasting techniques

The BKG, in cooperation with the University of Dortmund, has developed a technique for streaming GNSS data to mobile users. This technique establishes the open none-proprietary “Networked Transport of RTCM via Internet Protocol” (Ntrip, see *Radio Technical Commission for Maritime Services 2003*). Ntrip stands for an application-level transmission protocol based on HTTP where objects are enhanced to data streams. It is designed for disseminating differential corrections or other kinds of GNSS streaming data to stationary or mobile users, allowing simultaneous PC, Laptop, PDA, or receiver connections to a broadcasting host. It supports wireless access through Mobile IP Networks like GSM, GPRS, EDGE, or UMTS. The major characteristics of the concept are:

- Based on the popular HTTP streaming standard; comparatively easy to implement when having limited client and server platform resources available.

- Application not limited to a particular plain or coded stream content; ability to distribute any kind of GNSS data.

- Potential to support mass usage; disseminating hundreds of streams simultaneously for up to thousand users possible when using modern Internet Radio broadcasting software.

- Considering security needs; stream providers and users don't necessarily get into contact, HTTP streaming often not blocked by firewalls or proxyservers protecting Local Area Networks.

- Enables streaming over any fixed-line or Mobile IP network because of using TCP/IP.

The following three software components are part of the protocol implementation: NtripServers, which transfer the data from one or multiple sources to an NtripCaster, the major stream-splitting and broadcasting system component, and NtripClients which receive data of desired sources from there (see Fig. 1).

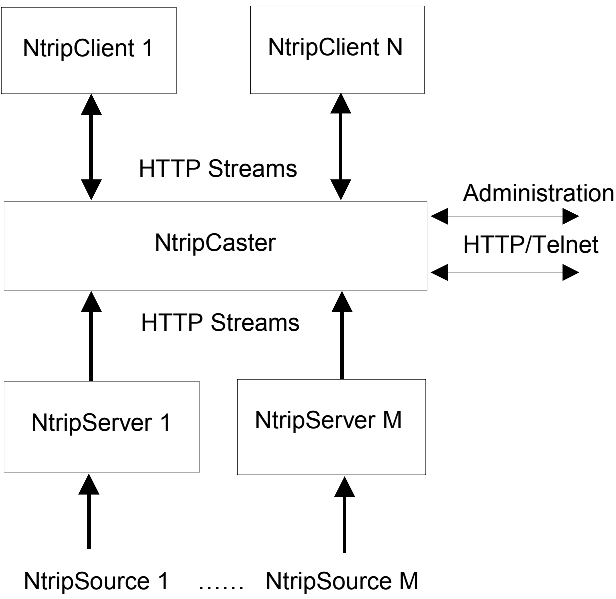

Fig. 1: Ntrip Streaming System

2. Ntrip Components

The **NtripServer** is used to transfer GNSS data of an NtripSource to the NtripCaster. Before transmitting data using a TCP/IP connection, the NtripServer sends an assignment for a so-called mountpoint that is allocated to the specific data stream. Mountpoints and server passwords are defined by the administrator of the NtripCaster. An NtripServer in its simplest set-up is a PC computer program which sends NtripSource data to the NtripCaster as received e.g. via the serial communication port from a GNSS receiver.

The NtripServer has to connect to the NtripCaster using its IP and listening Port. This means, that the NtripCaster has to be up and running before any source can connect. Before transmitting GNSS data to the NtripCaster using the TCP/IP connection, the NtripServer has to send an Ntrip server message to get access to a specified mountpoint. This server message is designed as HTTP message "SOURCE", an extension to HTTP 1.1:

SOURCE <password> <mountpoint> <CR><LF>
Source-Agent: NTRIP<product|comment><CR><LF>
<CR><LF>

where <*password*> is the encoder password of the NtripCaster, <*mountpoint*> is the NtripCaster mountpoint for the Source, and <*product|comment*> is information about the source agent. The password is not protected. Like in the HTTP Basic Access Authentications scheme, this assumes that the connection between the client and the server can be regarded as a trusted carrier.

The **NtripCaster** is basically a HTTP server supporting a subset of HTTP request/response messages. It is adjusted to low bandwidth streaming data (about 0.5 to 5 kbit/s per stream). NtripClient and NtripServer are acting as HTTP clients. The NtripCaster accepts request-messages from either the NtripServer or the NtripClient. Depending on these messages, the NtripCaster decides whether there is streaming data to receive or to send. An NtripServer might be a part of the NtripCaster program. In this case only the capability of receiving NtripClient messages is implemented in the combined NtripServer/NtripCaster.

The NtripCaster maintains a source-table containing records with detailed information characterizing NtripSources, networks of NtripSources, or NtripCasters. The source-table, with its meta-data, is send to an NtripClient on request. Based on source-table information, a client has the possibility to select a data streams of his region containing data in the format he needs. The attributes of data streams, such as identifier, coordinates, format, GNSS system, mountpoint, *etc*., are available from the NtripServer for each reference station.

It is important to understand that IP-streaming for broadcasting purposes is the basis of Internet Radio software. Having the opportunity to use already existing Internet Radio source code resources, and just disseminate GNSS data streams instead of audio data, is a significant advantage when developing an NtripCaster.

An **NtripClient** is accepted for receiving data from an NtripCaster after sending a request message. Concerning message format and status code, the NtripClient-NtripCaster communication is fully compatible with HTTP 1.1, but Ntrip uses only nonpersistent connections. A client's request is designed as a HTTP message similar to the Ntrip server message. The client needs to know the mountpoint of the desired data stream. The message for requesting a data stream is:

GET <mountpoint> HTTP/1.0 <CR><LF>
User-Agent: NTRIP<product|comment><CR><LF>
Authorization: Basic <user:password> <CR><LF>
<CR><LF>

where <*mountpoint*> stands for the NtripCaster mountpoint of the requested source, <*product*| *comment*> is information about the user agent originating the request, and <*user:password*> is a base64-coded string used for authentication and authorization.

4. Ntrip Implementation

In June 2002, the IAG Sub-commission for Europe (EUREF) adopted a resolution to disseminate differential corrections in RTCM format via Internet for DGPS positioning and navigation purposes. EUREF's Permanent Network (EPN), comprising approx. 160 continuously operated and continental-wide distributed GNSS reference stations, intends to add an Ntrip-based real-time component to its so fare post-processing oriented services. These activities are known as EUREF-IP (IP for Internet Protocol).

Within the framework of EUREF (see *EUREF-IP Real-Time Pilot Project*), NtripClient, NtripCaster, and NtripServer software has been developed for various operating systems (see *Ntrip Homepage*). Client software is available for Windows Desktop, Windows CE, PalmOS and Linux platforms. Server programs are available for Windows Desktop and Linux systems. An NtripCaster has been derived from the ICECAST Internet Radio under GNU General Public License. Due to some advantages of Linux systems, the NtripCaster development focused on that but a Windows version may become available later.

EUREF operates a number of NtripCasters today that provide GNSS real-time data in various formats (DGPS and RTK corrections in RTCM format , EGNOS and WAAS data in RTCA and RTCM format, SP3 Ultra-Rapid Orbits, observation data in RINEX format etc.). Operated on a high performance DELL Power Edge Linux workstation, BKG's NtripCaster has proven its potential for mass usage. It has been tested under heavy workload when serving up to one million short-time connected DGPS NtripClients per day. While hosted within the premises of a professional Internet Service Provider, the availability of the system over the period of several weeks was continuously better than 99.5%. The function of BKG's NtripCasters is monitored by an alarm system that generates "Notice Advisories to Broadcaster Users" (NABUs). If a data stream is unavailable for several minutes due to any reason, the monitor system creates a NABU message and sends it by e-mail to the affected stream provider. An additional message is sent when the stream becomes available again. All messages are stored in a NABU Archive. Daily-generated outages graphics and tables show the individual as well as the overall availability of data streams.

EUREF's goal is to establish and maintain a well distributed network of NtripCasters, all linked with each other. Each implementation may provides access to regional as well as some global data streams. Following this idea, seamless distributed streams are accessible from everywhere with reduced latency while sharing the workload of broadcasting. Besides EUREF with its EPN, a number of public and private institutions has indicated interest in providing DGPS, RTK or raw data over the Internet. Many of them, like the IGN, already make available their data through EUREF's NtripCasters. An overview of today's availability of real-time GNSS data via Ntrip is given in Fig. 2. Furthermore, all distinguished manufacturers of GNSS receivers work together today under the umbrella of RTCM for the standardization of Ntrip and for its integration in their products. RTK software as well as reference station and rover equipment will support the Ntrip protocol in the future.

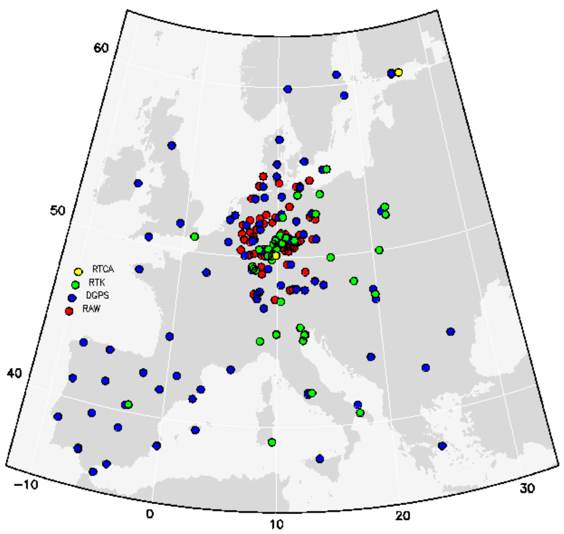

Fig. **2**: Real-time GNSS data streams available in Europe, status April 2004

5. IGN Field Tests in Madrid

The IGN decided to participate in the EUREF-IP project with a reference station in Madrid already providing differential correction in RTCM format for the "Radio Aided Satellite Navigation Technique" (RASANT) DGPS service. This is just a first stage. The IGN is currently considering to broadcast data from more stations of the Spanish ERGPS network via Internet using the Ntrip protocol.

The Madrid reference station was specifically designed for real-time purposes. The GPS equipment consists in a double GPS L1/L2 reference station and a third GPS receiver as an integrity monitor. All receivers are monitored by a control software. They are linked by serial connections for exchanging Reference Station Integrity Monitor Message 20 (RSIM20). The RTCM messages generated are 1, 2, 3, 16, 18, and 19. These messages are sent with NtripServer software to BKG's NtripCaster implementation in Frankfurt for further dissemination. The station is located on the roof of a building at the IGN (monument IE09) belonging to the IBERIA95 ETRS89 Class-B network. The station shall support RTK positioning in the metropolitan area of Madrid.

Initial tests employing a 56K modem mobile Internet connection over a 50m baseline between two IGN buildings showed a centimeter accuracy and latencies of RTK corrections less than 2-3 seconds. In order to see the wireless technology benefits, additional test at 5, 10, 15, 20, and 27 kilometer distance from the Madrid reference stations have been carried out (see Fig. 3 for a bench mark example).

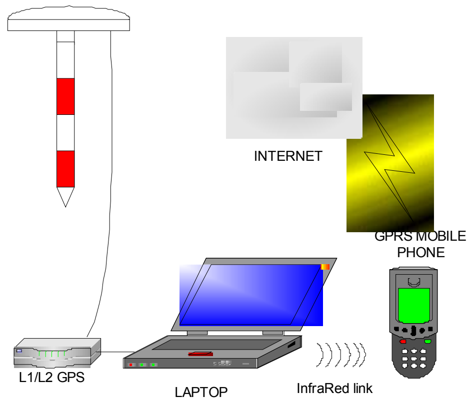

Figure 3: Bench mark Villafranca, 20 km distance from Madrid reference station (left), and General diagram of GPS rover configuration (right)

The equipment used consists of a dual frequency GPS receiver with OTF capability, a laptop, and a GPRS mobile phone connected to the laptop using an infrared link. The laptop provided RTK messages (GNSS Internet Radio, input to the GPS receiver) and recorded NMEA messages (output from GPS receiver) by means of a standard serial port connection.

6. Test Results

After carrying out the observations, the log-files have been analysed with a MATLAB software tool (see Fig. 4). The results, compared with precise surveyed coordinates, show that even at 20 km distance to the reference station a centimeter accuracy can be achieved after about one minute initialization time for fixing the ambiguities.

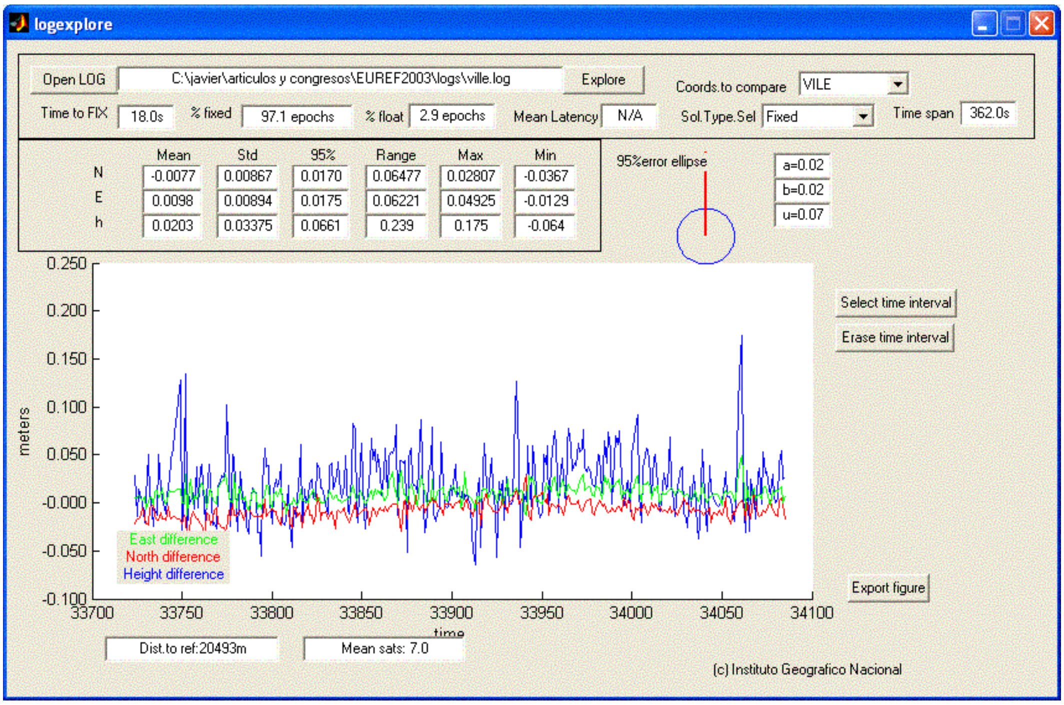

Figure 4: NMA explorer, with

Sol. Tipe sel : Select among NMEA file solution: Autonomous, RTCM, Float, Fixed
Time to fix : Time between first RTCM and first FIXED positions
% fixed: Fixed positions / (RTCM+float+fixed positions)*100
% float: Float positions / (RTCM+float+fixed positions)*100
Mean latency: Deduced from GGA message if available
Time span: Selected solution duration in seconds

The average site occupation time at each location was 7 minutes. The log-files have been split in four parts according to Fixed, Float, RTCM and Autonomous solutions. Most of the log-file records show fixed solutions. Site "Lomo" was an exception because fixing ambiguities was not successful over a distance of about 27 km.

Test results as shown in Tab. 1 need a careful interpretation. They are valid for observations carried out under similar conditions in a comparable equipment. For a reliable generalizing conclusion, the observation time per station needs to be extended to at least several hours. The accuracy depends strongly on the satellite configuration as expressed in terms of the PDOP and the number of tracked satellites.

Fixed solution						
Distance to reference [m]	East difference [m]	North difference [m]	Height difference [m]	Satellites tracked	Time span [sec]	Point
5015	-0.008	0.006	0.028	10	429	BM5
10403	0.003	0.008	0.046	6	105	BM10
10403	0.014	0.023	0.022	8	357	BM10
14649	-0.014	0.055	0.008	5	460	BM15
14649	-0.041	0.034	0.010	9	374	BM15
20493	0.010	-0.008	0.020	7	362	VILLE
20640	0.007	0.021	0.021	9	134	VILLT
27568	No fix					Lomo

Float solution						
Distance to reference [m]	East difference [m]	North difference [m]	Height difference [m]	Satellites tracked	Time span [sec]	Point
5015	-0.020	-0.111	0.197	10	51	BM5
10403	0.247	0.299	0.768	6	541	BM10
10403	0.147	-0.369	0.036	8	82	BM10
14648	0.286	0.051	1.000	5	192	BM15
14649	-0.009	0.073	0.442	9	8	BM15
20493	-0.464	-0.304	-3.164	7	11	VILLE
20640	-0.745	0.283	-0.163	8	89	VILLT
27568	0.156	-0.493	0.342	8	600	Lomo

RTCM solution						
Distance to reference [m]	East difference [m]	North difference [m]	Height difference [m]	Satellites tracked	Time span [sec]	Point
5015	-0.026	-0.203	-0.113	10	56	BM5
10403	0.216	0.092	0.784	6	124	BM10
10403	-0.360	-0.028	-0.905	8	43	BM10
14649	0.112	-0.624	0.893	5	6	BM15
14649	-0.082	-0.147	0.679	9	5	BM15
20492	0.234	0.335	0.229	7	6	VILLE
20640	-0.322	0.293	-0.090	8	62	VILLT
27568	0.048	-0.760	0.583	8	5	Lomo

Autonomous solution						
Distance to reference [m]	East difference [m]	North difference [m]	Height difference [m]	Satellites tracked	Time span [sec]	Point
5018	-1.288	-2.022	7.874	10	202	BM5
10400	0.511	5.678	21.232	6	176	BM10
10405	-2.580	1.687	10.283	8	32	BM10
14646	1.158	3.620	15.971	5	15	BM15
14648	1.017	-1.567	11.380	9	119	BM15
20493	-0.160	2.648	14.200	7	45	VILLE
20639	0.528	1.389	14.271	8	187	VILLT
27570	-2.335	3.668	18.148	8	59	Lomo

Table 1: Test results, seperated by type of solution

7. Conclusions

From the data providers point of view, the Ntrip technology solves a number of problems compared to transmitting GNSS data using a traditional radio provider (i.e. National Radio of Spain and RDS subcarrier). In particular, accessing the broadcasting network is easier and inconveniences from a limited bandwidth don't occur. "Digital Audio Broadcasting" (DAB) technology is actually able to provide enough bandwidth, but this network is designed to cover the area of a whole country. This means that just one stream can be disseminated. Sending RTCM or RTK corrections for different areas is quite difficult.

The tests have been done using an infrared link between a laptop and a mobile phone. This led to latencies of about 3 to 4 seconds when using an NtripCaster in Frankfurt. A more robust configuration i.e., a PDA with GPRS capabilities and even with an integrated GPS will improve this 4 seconds delay especially when using an NtripCaster operated on the Iberian Peninsular.

The Internet technology is the future in wireless telecommunications. Accessing an IP network from everywhere is becoming more and more easy. Note that WI-FI technology provides

Internet access in urban areas at inexpensive cost level and some cities are completely covered by this technology today. We are in need of a dense real-time GNSS reference network that also allows the usage of "Virtual Reference Stations" (VRS). The IGN intends to integrate parts of its ERGPS network in the EUREF-IP project with DGPS data in RTCM format while continuing with transmitting RTK corrections from Madrid in support of central caster requirements.

Finally, when connecting to the Internet with GPRS, the user pays for the amount of data transferred. Surveying a single point needs transferring an average of 200 Kbytes in real-time. Nowadays a 20Mb pack is offered at costs of 30 Euros or less by mobile telephone companies. Therefore one point can be surveyed precisely in Madrid for 0.40 Euros approximately.

References

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