EUREF-IP: From Pilot Project to Professional Service

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1. Abstract

In June 2002 EUREF decided to set up and maintain a GNSS real-time infrastructure on the Internet using stations of its European Permanent Network (EPN). A pilot project has been established called EUREF-IP (IP for Internet Protocol) which uses the dissemination standard NTRIP (Networked Transport of RTCM via Internet Protocol) for streaming the data.

Since the initiation of the project, the number of stations contributing to EUREF-IP is steadily growing. Today about 40 EPN stations upload their data in real-time. The Internet has proven to be a reliable transport media for many applications. NTRIP is accepted as an international standard and is already integrated in commercial hard- and software tools. Monitoring systems exist to control the data streaming to keep outages of individual stations as short as possible.

This first part of this paper summaries the current activities within EUREF-IP. The progress in participation and stream availability is described as well as the cooperation/coordination with IGS real-time activities. The second part provides future plans for the EUREF-IP pilot project and its development towards a professional real-time service. A major focus will be the definition, generation, and dissemination of real-time EUREF products. In addition, the EUREF-IP data flow will be discussed as well as quality standards and quality checks. The presentation will close with considerations concerning policy aspects.

2. Current Status of EUREF-IP Real-time Network

More than a thousand GNSS data streams are available through NTRIP, primarily from Europe and the US. About 35 NtripCasters support the dissemination of real-time data from reference stations or Virtual Reference Stations (VRS) in various formats, see [1] and [2]. Some implementations split a few hundred incoming raw GNSS data streams or derived products for up to a thousand simultaneously listening clients.

Within Europe, more than 40 EPN station are contributing to the real-time activities of EUREF (Fig. 1). They are sending at least one data stream to at least one EUREF-IP NTRIP Broadcaster. Currently, five NtripCasters are operated within the framework of EUREF-IP (Fig. 2). Most of the stations are sending RTCM 2.x data. At the moment the following formats are in use:

- RTCM 2.0, DGPS corrections (9)
- RTCM 2.x, RTK (32)
- RAW, vendor formats (12)

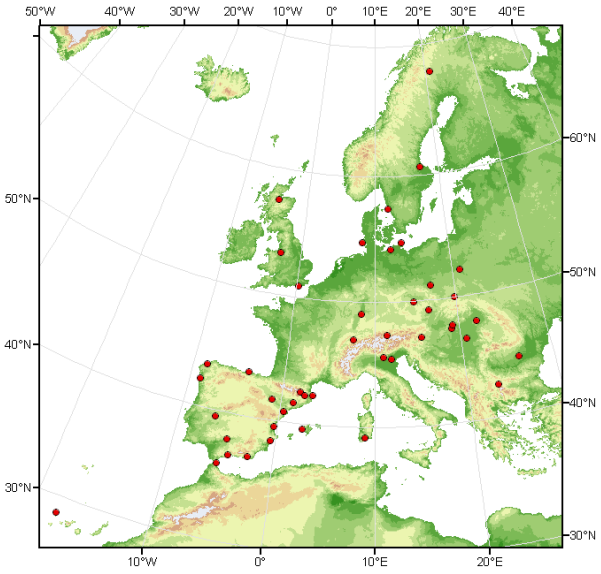

Fig. 1: EUREF-IP stations (45)

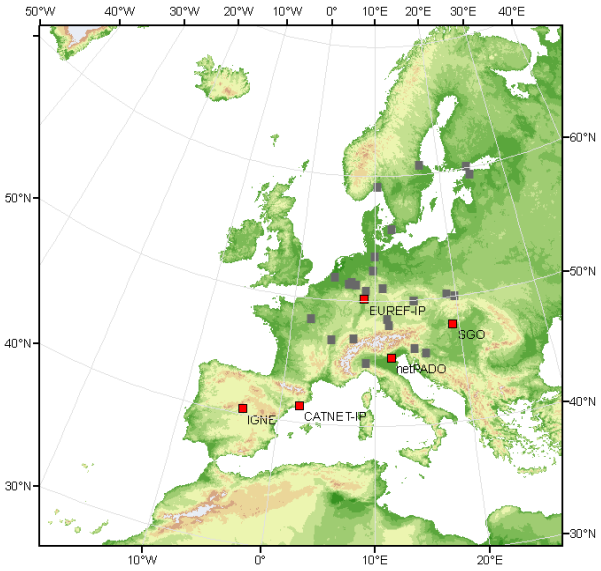

Fig. 2: EUREF-IP Broadcasters (5)

3. Transport Protocol NTRIP 1.0

In the framework of EUREF-IP the development of a new dissemination standard was initiated, called "Networked Transport of RTCM via Internet Protocol" (NTRIP). NTRIP is a generic, stateless application-level protocol based on the Hypertext Transfer Protocol HTTP Version 1.1. It is designed to disseminate differential correction data (e.g. in the RTCM-104 format), or other kinds of GNSS streaming data, to stationary or mobile users over the Internet, allowing simultaneous PC, Laptop, PDA, or receiver connections to a broadcasting host. NTRIP supports Wireless Internet access through Mobile IP Networks like GSM, GPRS, EDGE, or UMTS because of using the TCP/IP protocol. In September 2004 the Radio Technical Commission for Maritime services Special Committee 104 (RTCM SC-104) adopted NTRIP 1.0 as an international standard. NTRIP is now accepted by many users and receiver manufacturer and became part of various hard- and software tools.

In case of professional services it is important to pay attention to Internet security issues to protect providers and clients, to simultaneously serve as many clients as possible and to incorporate a mechanism to maintain meta-data. These have been the reasons for designing the NTRIP concept involving the following three system components:

- NtripServers, forwarding data from NtripSources,
- NtripCaster, the major stream-splitting, broadcasting and meta-data maintenance system component,
- NtripClients, receiving data of desired sources to feed a GNSS application.

The NtripCaster is the actual HTTP server program whereas NtripClients and NtripServers are acting as HTTP clients.

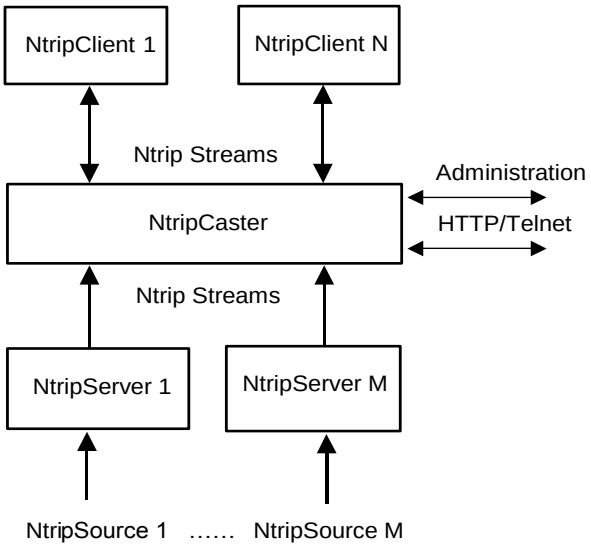

Fig. 3: NTRIP system components

The major characteristics of NTRIP are the following:

- It is based on the popular HTTP standard, and is comparatively easy to implement when limited client and server platform resources are available.
- Only one Internet port is used, normally HTTP port 80
- Its application is not limited to one particular plain or coded stream content. It has the ability to distribute any kind of GNSS data streams.
- NTRIP provides meta-data information together with the data stream itself through the so called sourcetable.
- It has the potential to support mass usage. It can disseminate hundreds of streams simultaneously for up to a thousand users when applying modified Internet radio broadcasting software.
- As for security needs, stream providers and users are not in direct contact. Streams are usually not blocked by firewalls or proxy servers protecting Local Area Networks.
- It enables streaming over any mobile IP network using TCP/IP.

More details about NTRIP 1.0 can be found in [3].

4. NTRIP Software Tools

In order to receive or to send real-time GNSS data streams via NTRIP, a software tool is necessary. This may be a stand-alone software or an application component. Typically, the NtripClient is part of an application terminal, e.g. a Pocket PC, a mobile phone, or a GPS receiver. NtripServers could run on separate PCs or directly in the station's GNSS receiver. Numerous NtripClient and Server implementations exist for different operating systems. Some of them – developed within the framework of EUREF-IP – are available from a download web-page [1].

Ntrip Client

- Windows: GNSS Internet Radio
- Windows CE & PocketPC 2003: GNSS Internet Radio
- Linux: Plain Example Program, GNU GPL
- Linux: Perl NtripClient, GNU GPL
- Palm OS: Demo Example Program

Ntrip Server

- Windows: Reading from Serial Port
- Windows: Command line version, reading from IP address/port
- Linux: Reading SISNeT, TCP/UDP Port, Serial Port, NtripCaster, GNU GPL
- Linux: Perl NtripServer, Reading from Standard Input, GNU GPL

Ntrip Decoder, Converter, etc

- Windows: GnssSurfer, Client & Server & RTCM 2.x Decoder
- Windows: RTCM 2.x DGPS/RTK Decoder, reading from TCP/IP Port
- Linux: Stand-alone RTCM 2.x RTK Decoder, reading from Std. Input, GNU GPL
- Linux: Multi-Stream Client and RTCM 2.x to RINEX Converter, GNU GPL
- Linux: Client and RTCM 3 to RINEX Converter, GNU GPL

Plus variety of commercial Ntrip supporting hard and software products

Fig. 4: EUREF-IP Software Tools

5. RTIGS-NTRIP Interface

The EUREF Permanent GPS Network is the European densification of the Global Network of the International GNSS Service (IGS). Like EUREF, the IGS started to upgrade its network to real-time. Some years ago, a real-time IGS working group (RTWG) was established which is now about to kick of a pilot project to enhance its real-time activities.

Within IGS the so-called RTIGS transport protocol is used to disseminate the real-time data streams. It is based on UDP protocol and uses the SOC data format, see [4].

A concept has been developed to integrate RTIGS and NTRIP [5]. The following graphic shows the data exchange between the different systems.

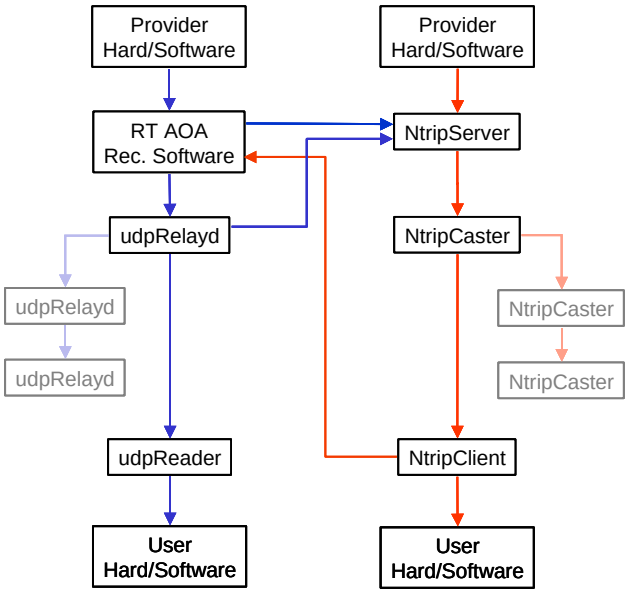

Fig. 5: RTIGS – NTRIP Interface

It is recommended that each EPN station which is also part of the IGS network provide its data via NTRIP as well as RTIGS. This is not necessarily done by sending two different streams from the station. It is also possible to transport RTIGS format via NTRIP or to receive RTIGS from an NtripCaster. Which way is the best depends on the situation at the station and should be decided individually.

6. Plans for EUREF-IP Network Structure

The aim is to upgrade as many EPN stations as possible to real-time. Any provider must guarantee up to 10 kbits/sec Internet bandwidth per provided stream in order to allow a continuous uninterrupted service. A new EUREF-IP station will be accepted in case it provides at least one real-time data stream. It is also possible to send more than one stream and to support different data formats (e.g. RTCM 3.0 and RTIGS). The real-time data streams have to be send to one or more EUREF Broadcasters. In order to ensure a high quality service it is important to continuously monitor the stream availability as well as the stream content (see chapter 7).

For the dissemination of real-time GNSS data it is important to use a standard data format (in addition to a standard transport protocol) like RINEX in post-processing. This should be a format which meets EUREF requirements and is accepted by the clients and usable by many receivers and software tools (industry standard data format). Because of its minimal bandwidth requirement the new format RTCM 3.0 is best suited for the dissemination of EUREF-IP observations via Internet. For more details concerning RTCM 3.0 refer to [6].

The dissemination of EUREF-IP real-time data streams will be done by one or more NtripCasters. One European Broadcaster provides access to all EPN stations. This caster should be operated by a Regional Data Centre (RDC) in analogy to the daily and hourly data flow. The EUREF-IP Broadcaster running at "www.euref-ip.net" is ready to disseminate data from all EPN stations. In addition, further Broadcasters (local hubs) should disseminate data streams from smaller regions (regional or local data streams). It is recommended that each Local Data Centre (LDC) will operate a Broadcaster. Operational Centres (OCs) are also welcome to participate in case the necessary resources are available. The goal is to establish and maintain a well distributed network of NtripCasters, all linked with each other. Following this idea, seamless distributed streams are accessible from everywhere with reduced latency while sharing the workload of broadcasting.

7. Stream Control

To keep the high quality standard of the EUREF data an adequate testing of accuracy and reliability is necessary. This could be done in four steps and is only partly introduced yet.

1. Caster Outage Monitoring
At first, testing if all casters are available and ready to receive and disseminate data streams (comprising caster host and caster software) is necessary. This could be done from an independent NtripMonitor and/or from other Broadcasters within the caster network (e.g. by means of "ping").

2. Stream Outage Monitoring
The next step is to monitor the availability of each data stream on each caster. In case of dynamic sourcetables (the caster only provides data streams in the sourcetable which are online) this could be done by comparing the received sourcetable content with the full sourcetable (e.g. BKG's Professional NtripCaster, Trimble's TNC). If the Broadcaster works with a static sourcetable (e.g. BKG's Standard NtripCaster) the

monitor should try to receive each data stream with an NtripClient - only for a very short period to keep the used bandwidth low.

3. Stream Content Monitoring
In addition to the availability of the data streams their reliability is very important. In order to ensure the usability of the data the stream content has to be checked. The first and easiest step would be to compare the stream format with the stream description given by the sourcetable. This could be done by using decoder software, e.g. TEQC in case of vendor formats or an RTCM converter in case of RTCM data streams (available for RTCM 2.x and RTCM 3.0). If the adequate converter program can translate the data to RINEX the stream contents would be suspected to be correct.

4. Stream Quality Monitoring
In order to check the quality of the data streams as well as the accuracy of the GNSS measurements a detailed analysis of the data content is necessary. This could be done by using the RINEX files produced within the Stream Content Monitoring. The data validation could be done with the TEQC program. Like for EPN post-processing files, at least the number of observations and the number of observed satellites should be checked.

A further step would be to use the RINEX files from streams to perform a Precise Point Positioning (PPP) to ensure the quality of the data stream. This check would need additional information which is not included in the real-time data stream and has to be extracted from the station log files (e.g. antenna parameters) or from other archives (e.g. reference coordinates). This check would be optional and has a strong connection with the product generation which is the reason that it should be done by the Analysis Centres (ACs) and not by the data centres.

A serious stream quality monitoring is not possible in real-time but could be performed in near real-time, e.g. hourly or every 15 minutes. It could not be done for RTCM 2.0 data streams (DGPS).

8. Products

The availability of data streams is the most important step towards a real-time EUREF network. These observations could be used to generate real-time products. Some products could be already computed today others as soon as enough EUREF real-time streams become available and adequate software and dissemination formats are developed.

It may be that not all of the products have to be computed in real-time. In some cases a near real-time product generation is sufficient or forced by the processing strategies. Then, the real-time observations could be used to reduce the latency of these products.

Possible products could be:

- Reliable observations
- Event notification service
- Station coordinates (near real-time, from PPP)
- Real-time satellite clocks
- Real-time orbitsReal-time coordinates (e.g. for geodynamic applications)
- DGPS/RTK data streams

The product catalogue is currently under discussion within the EUREF Technical Working Group (TWG). Efforts are made to develop adequate software tools to generate these products and to define appropriate formats for them.

9. Dissemination Policy

EUREF will charge no user fee for the reception of EPN real-time data streams via NTRIP. A user will only have to pay its own communication costs. This open data policy should be the same as for EPN post-processing data and products.

However, the caster operator may temporarily block one or more data streams for one or all users because of technical or other issues, e.g. in case of bandwidth limitations at the caster side. To ensure adequate data latencies the number of simultaneously connected clients has to be limited and a priority list should become active.

If a stream provider or a caster operator wants to handle classified data following commercial interest this should not be done under the umbrella of EUREF. Nevertheless, these data could be transported by EUREF NtripCasters in addition to EPN streams but not in the EUREF network. There should be no disadvantages for EPN real-time streams (e.g. reduced latencies because of the additional streams). The main European Broadcaster will not disseminate commercial data streams and will not perform any billing.

10. Summary and Recommendations

The real-time activities of EUREF will be extended and developed to a more professional service. Part of these activities will be the upgrade from as many EPN station to real-time as possible. Each station operator is encouraged to generate high-rate data streams in addition to the hourly our daily RINEX files. The use of RTCM 3.0 is recommended. The data streams should be provided free of charge to all interested users.

To ensure a reliable service EUREF will operate a network of NTRIP Broadcasters and will continuously monitor the stream flow and content to guarantee a high quality of real-time data.

A real-time working group within the TWG has been established to further promote the EUREF real-time activities, to define EUREF real-time products and adequate product formats, and to decide on the development of an adequate real-time processing software.

References

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[4] Real Time IGS Working Group
http://igscb.jpl.nasa.gov/projects/rtwg/index.html

[5] Georg Weber, "*Streaming Real-Time IGS Data and Products Using NTRIP*", Proceedings of the IGS2006 Workshop, ESOC Darmstadt, Germany, May 2006, in press

[6] Radio Technical Commission for Maritime Services, "*RTCM Recommended Standards for Differential GNSS Service, Version 3.0",* RTCM Paper 30-2004/SC104-STD