# Real-Time GNSS in Routine EPN Operations

# Concept

EPN Real-time Working Group
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# 1 INTRODUCTION AND MOTIVATION

EUREF has established a permanent GNSS network (EPN) of about 180 stations. All these stations are delivering daily observation files with 30 second sampling rate in the well-known RINEX format. In addition, the EPN started delivering hourly files in 2003. Up to now, approximately 130 EPN stations are sending those hourly files primarily motivated by their usage in the so-called near real-time analysis for meteorological purposes.

In the past, the demand for data with 1 Hz sampling rate grew for a number of geodetic applications. This applies to, for example, the Low Earth Orbiter missions CHAMP and GRACE. In parallel, the growing capacities of the Internet allowed improvements in the real-time transport of data and long-term archiving became less expensive. Meanwhile applications that transfer continuous data streams by IP-packages, such as Internet Radio, are well-established services. To keep pace with this evolving technology, EUREF decided in June 2002 to set up the EUREF-IP Pilot Project aiming at testing the real-time transmission of GNSS data from its EPN stations.

Today about 50 EPN stations participate in EUREF-IP by streaming their GNSS data (in several formats) over the Internet using the NTRIP protocol as developed within the Pilot Project. NTRIP became a Recommended RTCM standard; vendors have integrated NTRIP client software in their equipment and local permanent GNSS networks now stream real-time data in support of network RTK applications. Thanks to the advantageous cost-benefit factor (communication costs for real-time data streaming are about 30€ / month), more and more EPN stations are joining the EUREF-IP Pilot Project.

From the technical point of view the NTRIP technique as well as the EUREF community have reached a sufficient level of maturity to enhance the EPN services by adding real-time data streams to the routine data flow operations.

Since the EUREF-IP Pilot Project already started some years ago, the scope of this paper goes beyond a pure description of the existing technology. It proposes how the EPN structure shall be adapted by adding new components to integrate real-time data streams in the routine EPN operations. For each of the EPN components the responsibilities are outlined and a proposal for monitoring procedures is developed to ensure that the EPN GNSS data streams respond to the highest quality standards targeting a large user community.

The main motivation for EUREF to disseminate, in addition to the daily and hourly data, real-time GNSS data streams from EPN reference stations (including validated station coordinates) is that this new service will provide the user community with a homogenous European-wide real-time access to the European Terrestrial Reference System ETRS89 (EUREF's core business). Furthermore, the dissemination of GNSS data streams follows the purposes of the GGOS project of the IAG and the needs of a wide community of users in the geophysical and meteorological communities to access accurate and reliable GNSS data in real time.

Last but not least, EUREF is the only organization in Europe in a position to maintain a European-wide real-time GNSS network following an open data policy. EUREF's real-time GNSS network will therefore not only support EUREF-specific applications (like the monitoring of the motion of reference stations through the computation of (near) real-time coordinates), but it will also be an enabler for new European-wide applications within the fields of positioning, navigation, safety and science, commercial and non-profit.

The paper takes into consideration the already existing strategies and techniques which are used within the EUREF community to adapt and analyse GNSS data of the EPN.

## 2 EPN REAL-TIME COMPONENTS

In order to integrate the EUREF-IP real-time data streams in the EPN routine operation the existing EPN structure is extended by a number of new components while some of the already existing EPN components take over additional functionalities. The real-time data flow is illustrated in Fig. 1 with respect to the existing EPN structure.

It is important to understand that all real-time system components can be globally spread over the Internet and consequently handled by different operators at different locations. The new components may also be hosted by existing facilities.

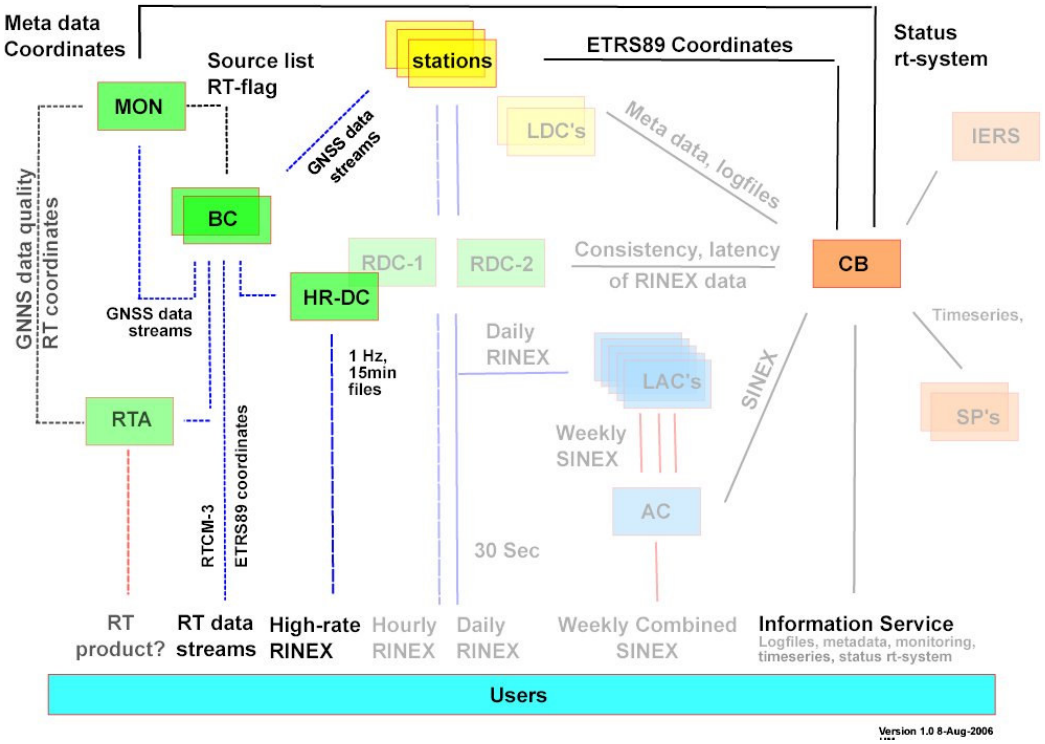


**Fig. 1: New EPN Structure**

**Table 1: EPN Real-time Components**

| | Description |
|---|---|
| Stations | EPN Real-time Stations |
| BC | Broadcaster |
| HR-DC | High-rate Data Centre |
| MON | Monitoring and Validation |
| RTA | Real-time Analysis Centre |
| CB | EPN Central Bureau |

## 2.1 Stations

The aim is to upgrade all existing EPN stations to real-time as far as on-site Internet communication allows. Candidate EPN stations should be motivated to provide real-time data in addition to the daily and hourly RINEX files by offering them acceptance with priority. Data streams should contain all carrier phase and code observations available together with the official ETRS89 coordinates and other meta data. For backup purposes streams are sent to two different broadcasters simultaneously whenever possible.

Maintaining a continuous and uninterrupted service is important. Station managers have to establish and maintain a minimum Internet communication link with a bandwidth of 10 kbits/sec per data stream in order to avoid network congestions. Details of how to become an EPN real-time station (including hard- and software components) are included in the EPN guidelines "Procedure for becoming an EPN station".

## 2.2 Broadcasters

The broadcaster receives streams from the stations and disseminates them to clients on request. Clients may be users, data centres, analysis centres or monitoring tools. The broadcaster does not change the content of the streams. The broadcaster maintains a so-called sourcetable containing meta data. The sourcetable is made available on request.

The regional (continental) broadcaster www.euref-ip.net (under the responsibility of BKG) provides access to all EPN streams. To ensure a high level of availability it is operated on the premises of an Internet Service Provider. It is doubled by a backup installation. In addition, local (national) broadcasters disseminate streams covering specific areas. This distributed network of linked broadcasters allows sharing the workload of stream dissemination while limiting latencies.

The streams on the regional broadcaster are grouped in networks representing status categories. In order to permit a consistent data management and a clear data identification, a specific naming of networks is introduced, see Table 2. The subdivision of streams in specific networks allows flagging a stream by moving it to another network in case the streams do not fulfil the EPN standards as defined in the "Guidelines for EPN stations and Operational Centres". Access to a flagged stream will be limited to station and broadcaster operators. The flagging of a stream is done by the EPN broadcaster on demand of the EPN CB. Broadcasters may support other networks apart from EUREF.

**Table 2: EUREF Broadcaster Networks**

| | Network | Description |
|---|---|---|
| 1 | EUREF | Streams from EPN stations |
| 2 | MISC | Streams from stations not part of the EPN |
| 3 | TEST | Streams made temporarily available (e.g. candidate EPN stations) |
| 4 | CORRUPT | Streams suspected to contain corrupt data |

Each EPN stream has a unique identifier, which is its so-called mountpoint. Upon integration of the stream into the EPN, the mountpoint will be attributed to the stream by the EPN CB and communicated to the regional and local broadcasters making available the data stream. The unique mountpoint (similar to the DOMES number for the EPN station marker) will then

be used to identify the EPN stream throughout all EPN broadcasters (regional and local). This implies that streams referring to mountpoints not known to the EPN CB will not be considered as part of the EPN. Note that an EPN station can stream several data streams, e.g. raw data and RTCM 3.0 data. Each of these streams will get its own mountpoint composed of the official EPN four-character ID plus an integer number (i.e. BRUS0) which indicates the format of the stream.

#### 2.2.1 Dissemination Policy and Authorization

EUREF follows an open data policy. Streams are made available free of charge to anyone for any purpose. Therefore, it is not clear today how many users of EUREF's real-time products will have to be simultaneously supported. The situation may develop in ways that become difficult to serve all registered users at any time. In case limited dissemination resources on the broadcaster side (software restrictions, bandwidth limitation etc.) make it necessary, first priority in stream provision will be given to stream providers, real-time analysis centres, and re-broadcasting activities while access for others may be temporarily denied.

Access to the real-time data streams is provided through a registration per broadcaster. The registration details are used to communicate with clients whenever necessary. Carrying out the registration is the responsibility of the affected caster operator.

### 2.3 High-Rate Data Centres

EPN real-time data streams provide the opportunity to generate RINEX files with any sampling rate for any small time interval. This possibility will be used to archive 1 Hz 15min RINEX files from all EPN stations for near real-time post-processing applications.

Two high-rate data centres will continuously receive EPN real-time data streams. The function of a high-rate data centre is added to the already existing data centres. The high-rate data centre continuously receive streams coming in from the EUREF broadcasters and convert them to 15min 1 Hz RINEX batches. These batches are then archived. They constitute a new EUREF product for post-processing purposes introduced through a pilot phase. Data gaps in high-rate files as a consequence of temporary communication problems are accepted.

Note that in the past only reference station operators had the capability (and responsibility) to upload daily or hourly RINEX files. With the advent of real-time GNSS and stream conversion software, whoever has access to a data stream is capable of converting it into RINEX files for any small interval. This leads to a more complex situation that may require additional regulations in the future.

### 2.4 Monitoring and Validation

To join the standards of EUREF's post-processing products reached so far, a monitoring of real-time products is continuously carried out checking stream availability and content on the regional NTRIP broadcaster www.euref-ip.net.

#### 2.4.1 Stream Availability

The monitoring of the stream availability is done on a dedicated host not housing the broadcaster where monitor software checks the availability of all streams. This host is presently operated by BKG. In case of a dynamic sourcetable (streams that have an outage do not show up in the sourcetable) this is done by comparing the retrieved sourcetable content with the full sourcetable. In case of a static sourcetable (always containing any configured

stream independent from outages) the monitor connects to all streams - one after another - for a short period of time (i.e. 20 sec) to check the availability.

If stream outages appear, a message is sent to the affected stream provider by email. In addition, the outage information is made available to the EPN CB for integration in the EPN Web site.

#### 2.4.2 Stream Content

The validation of stream content comprises several checks, but it mainly concerns format and meta data checks which are the responsibility of the EPN network coordinator. Therefore these checks will be performed at the EPN CB. These checks will be performed, at least once a day, on all EPN data streams which are available from the regional broadcaster.

First, it is necessary to make sure that the stream format fits to the corresponding format data field in the sourcetable. This is done by using decoder or RINEX converter software like

- the “Rtcm2” decoder in case of streams coming in RTCM Version 2.x data format,
- the “Rtcm3toRinex” converter in case of streams coming in RTCM Version 3.0 data format,
- the “BKG Ntrip Client” (BNC) which integrates an RTCM 2.x, RTCM 3.0, and RTIGS decoder/converter,
- UNAVCO’s “Teqc” converter in case of streams coming in raw (vendor) data formats.

If a decoder can decode the stream or a converter can translate it to RINEX, it is supposed to be formally correct.

Secondly, details of the decoded/converted data are checked for consistency with other sourcetable entries, site log meta data (like antenna and receiver type, eccentricity), and coordinates, stream bandwidth, number of observed satellites etc. Furthermore, the latency is checked.

In case of a corrupt stream, the EPN CB updates its web site with this information, sends a message to the affected stream provider asking to check the situation, and informs the broadcasters which will flag the stream by moving it into a protected network of streams.

### 2.5 Real-time Coordinate Analysis

To check the quality of streams as well as the overall performance of stations, a regular data analysis is carried out in near real-time. For that a Precise Point Positioning (PPP) is performed once per hour based on the RINEX files available from the high-rate data. This activity shall be coordinated with and may become part the plans for an EPN Rapid Analysis.

The produced coordinates are made available to the EPN CB to generate time series and to check them against the official ETRS89 coordinates. In case of problems, the EPN CB informs the stream providers and the broadcaster operator so that the responsible stream may temporarily be flagged.

A real-time (instead of near real-time) data analysis is performed as soon as adequate software for this becomes available.

### 2.6 EPN Central Bureau

The EPN CB maintains a list of official ETRS89 coordinates for inclusion in real-time data streams by the station manager and for the validation of the real-time stream content. Note that if the reference station coordinates of a stream do not refer to ETRS89 this is explicitly mentioned in the broadcaster's sourcetable.

The EPN CB is responsible for the monitoring of the content of the real-time EPN data streams from the regional broadcaster. The web pages at the EPN CB are extended in order to integrate real-time status results concerning stream availability and content.

Details about the real-time activities within EUREF are given in the guidelines for station managers and the new guidelines for broadcasters, real-time analysis centres and high-rate data centres.

## 3 STREAM CONTENT, FORMAT, AND TRANSPORT PROTOCOL

The EUREF real-time data streams have to contain as many code and carrier phase observations as possible. It is recommended to also include information about the signal strength (carrier-to-noise ratio). In addition, information on the ETRS89 coordinates of the Antenna Reference Point and the antenna type and height are required.

The Update rate is 1 Hz for all observations and about 60 sec for static meta data contained in the stream.

Because of its small bandwidth requirements, its international standardization and the wide usage, the RTCM 3.0 data format is recommended for EUREF. RTCM 2.x is also accepted as long as full carrier phase information is included. Vendor formats are accepted under the condition that appropriate decoder software is freely available. Over time, EUREF will restrict the accepted formats to RTCM 3.0 only. Requirements for the stream content are given in the document "*Guidelines for EPN Stations & Operational Centres*" available from http://epncb.oma.be/_organisation/guidelines/guidelines_station_operationalcentre.pdf .

For the dissemination of the EPN real-time streams, only the NTRIP transport protocol is accepted. NTRIP software tools are made available for various platforms.

## 4 PRODUCTS AND SOFTWARE

Reliable real-time GNSS data streams will be among EUREF's most valuable products in the near future. They provide access to the reference frame and offer the opportunity to derive a variety of new products for geo-referencing or geo-science.

The EUREF-IP real-time services comprise a monitoring component from which station operators benefit through receiving notifications. In addition a real-time (or near real-time) monitoring of the EPN station coordinates is performed.

The real-time data streams are best suited to generate high-rate RINEX files in near real-time in support of post-processing applications.

EUREF will generate real-time clocks and orbits in cooperation with IGS efforts in that area. Today, there are only some software tools at hand that allow real-time data processing. EUREF supports the development of real-time software with access to source code. The generation of further real-time products beside clocks and orbits shall be considered as soon as the necessary software tools become available within EUREF.

Whatever is generated in real-time needs to be disseminated also in real-time following international standards. For that reason EUREF participates in the development of appropriate formats for its real-time products.

## 5 INTERFACE TO RTIGS

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 off 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 the UDP protocol and uses the SOC data format.

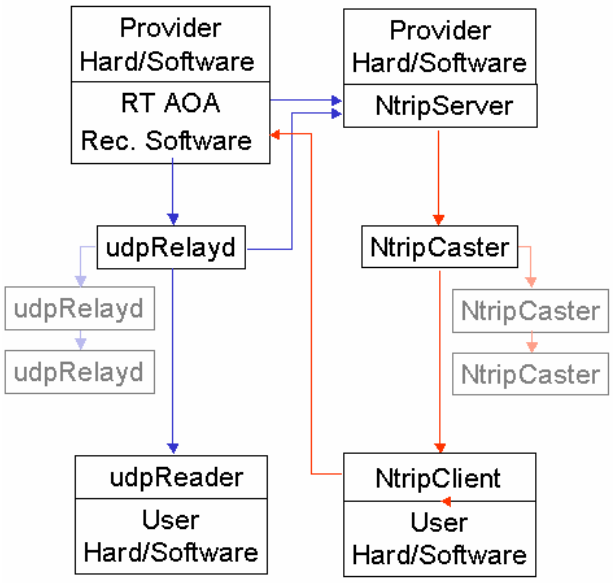


**Fig. 2: NTRIP – RTIGS Interface**

In view of the different approaches of EUREF and IGS in the real-time area, a concept has been developed to integrate resources from both sides. Fig. 2 shows the data exchange between the two systems. The aim is to set up an interface that makes any RTIGS stream available also in the NTRIP system and vice versa. EUREF operates the RTIGS->NTRIP interface part. NRCan operates the NTRIP->RTIGS interface part. The current transfer of RTIGS data from GFZ, Geoscience Australia and NRCan to EUREF's NTRIP broadcaster is given in blue. The transfer of streams via NTRIP to NRCan is given in red. For compatibility reasons it is recommended that EPN station operators follow the NTRIP approach and run an NtripServer when upgrading to real-time.

## 6 SCHEDULE

The major EUREF real-time components have already been set up as part of the EUREF-IP Pilot Project. Some of them are in operation since 2002.

The following is a list of additional activities to be carried out in the near future:

1. Extend content of DGPS Pilot Project streams with carrier phase data
2. Get more EPN stations upgraded to real-time
3. Set up regional broadcaster backup
4. Extend the monitoring from availability to content check
5. Extend the EPN CB web pages and guidelines
6. Establish high-rate data centres
7. Set up real-time analysis centre(s)

Topics 1 and 2 are understood as an effort of the affected station operators while the EPN CB is in charge of 4 and 5. A new Call for Participation shall look for contributions to cover topics 3, 6, and 7.

## 7 REFERENCES

EUREF-IP Pilot Project: http://www.epncb.oma.be/euref_IP
EUREF-IP Regional Broadcaster: http://www.euref-ip.net/home
Technical Background, NTRIP: http://igs.bkg.bund.de/index_ntrip.htm
RTCM Standards (NTRIP, RTCM 3.0, RTCM2.x): http://www.rtcm.org
RTIGS Working Group: http://igscb.jpl.nasa.gov/projects/rtwg/index.html