

Networked Transport of RTCM via Internet Protocol (Ntrip) – IP-Streaming for Real-Time GNSS Applications

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BIOGRAPHY

Dr. Georg Weber received his Degrees in geodesy in 1977 and 1985 from the University of Hannover, Germany. Since 1987 he has worked at the German Federal Agency for Cartography and Geodesy (BKG), currently in the position of a scientific director in the Department of Geodesy. Lately, his main focus is located in the field of real-time GNSS. He is a member of the EUREF Technical Working Group and the RTCM SC-104 and he is European Vice Chair of the CGSIC.

Dr. Denise Dettmering received her Dipl.-Ing. in geodesy from the University Hannover in 1997 and her doctoral Degree from the University of Stuttgart in 2003. She is currently working as a scientific employee in the Department of Geodesy at the BKG where she is involved in the development of Ntrip and the European Real-Time GNSS Pilot Project EUREF-IP.

Harald Gebhard studied Communication Engineering at Coventry University, Great Britain, and the Polytechnic University of Applied Sciences Konstanz, Germany, and received the B.S. Degree in 1996. He received his M.S. Degree in Electrical Engineering at the Ruhr University Bochum in 1999. Since then he has been with the Communication Technology Institute of the University of Dortmund and the Informatik Centrum Dortmund (ICD) working in the field of Internet real-time data transport, multimedia services and protocols.

Dr. Rudolph M. Kalafus currently consults with the Military and Advanced Systems group of Trimble Navigation. He is chair of Special Committee 104 of the Radio Technical Commission for Maritime services (RTCM SC-104), Recommended Standards for Differential GNSS Service, a position he has held since its inception in 1983. He worked at Trimble from 1988 until 2002, leading efforts to incorporate differential reference station and mobile capability into GPS receivers, and

developing airborne receivers. Dr. Kalafus received his Degrees in Electrical Engineering from the University of Michigan in 1966. He received the ION Satellite Division's Johannes Kepler award in 1992, and was elected as an ION Fellow in 2001. He served as President of the ION for the 2002-3 term.

ABSTRACT

In September 2004 the Radio Technical Commission for Maritime services Special Committee 104 (RTCM SC-104) completed a new standard which defines a protocol for streaming GNSS data to stationary or mobile users over the Internet. Titled "Networked Transport of RTCM via Internet Protocol (Ntrip)" the standard is named for the widely used RTCM data format, but it can also be used for streaming other kinds of data. The development of Ntrip was initiated by the German Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) within the framework of the EUREF-IP Pilot Project [1]. Although there are uses for stationary DGNS receivers that could access the Internet via landline, the growing availability of Internet service through the mobile telephone network was a persuasive reason to develop and formalize a publicly available Internet protocol for streaming DGNS data. Ntrip is designed to distribute 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.

RTCM's new Ntrip standard already proved to be useful in support of positioning and navigation applications worldwide. Future applications may comprise satellite orbit and clock estimation, satellite health monitoring, global or regional estimation of ionosphere parameters or local streaming of troposphere parameters for Networked DGNS/RTK services. The paper draws attention to IP-

streaming for GNSS applications via Ntrip and its potential for science and research as well as public and commercial services in many areas.

INTRODUCTION

Global Navigation Satellite Systems (GNSS's) provide geographical positioning information from a constellation of satellites in orbit to receivers at sea, on the ground, and in the air. The satellite signals can be corrected by using reference stations, which broadcast corrections to GNSS receivers nearby. This technique is known as Differential GNSS (DGNSS) service.

Typically, differential corrections have been broadcast over radio data links from single reference stations located in precisely known locations, to mobile receivers (rovers) located on the equipment whose position needs to be known. As the uses of DGNSS services have grown, governments and commercial service providers have established networks of reference stations. Using correction data from multiple reference stations, such as these networks provide, increases accuracy.

Various user communities profit from receiving terrestrial broadcasted real-time GNSS data. Positioning and navigation are not the only application in need for them. For many, replacing the usual radio data link with data streaming over the Internet to stationary or mobile users can be advantageous. Consequently, in March 2003 the RTCM SC-104 set up a working group "Internet Protocol" to adapt an appropriate – so far missing – new international standard named "Networked Transport of RTCM via Internet Protocol (Ntrip)" for IP-streaming of GNSS data. The Internet, being conceived as an open net, is particularly well suited to transmit data between different providers over long distances. Uniform structures across national borders on a continental or global level can easily be created.

NTRIP IP-STREAMING TECHNIQUE

The basic data streaming is accomplished in Ntrip by TCP/IP protocol stack. Several demonstrations based on a plain Serial-to-TCP conversion of streaming data on the reference-side (server) and TCP-to-Serial re-conversion on the rover-side (client) have shown the suitability of the TCP/IP protocol for streaming data to mobile IP clients [2].

However, 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 in accordance to the following three system components (see Fig. 1):

- 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.

NtripServers define a source ID called "mountpoint" for every streamed NtripSource. Several NtripClients can have access to the data of desired NtripSources at the same time by requesting a source by its mountpoint on the NtripCaster. If implemented in the NtripCaster program, authorized personnel may remotely control the NtripCaster via a password-protected Telnet session, or receive status information via a password-protected HTTP session using an Internet Browser.

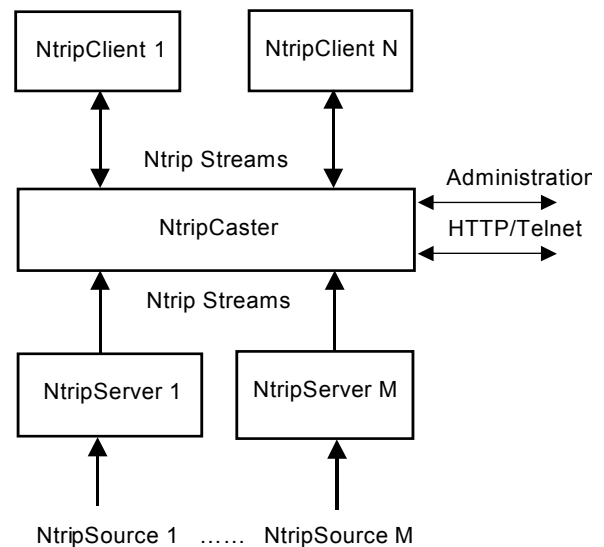


Fig. 1: Ntrip System Concept

The administrator running an NtripCaster is responsible for allowing new NtripServers to connect with new NtripSources. The administrator organizes all available NtripSources and defines the mountpoints.

The NtripCaster maintains a source-table containing information on available resources to be send to an NtripClient on request. Source-table records are dedicated to describe one of the following resources:

- Data Streams (record type STR)
- NtripCasters (record type CAS)

- Networks of data streams (record type NET).

NtripClients choose an NtripSource by its mountpoint on the NtripCaster. Each STR-record of the source-table contains meta-data describing attributes of a data stream. Stream attributes like identifier, approximate coordinates, data format, navigation system, mountpoint, etc. are defined at the NtripServer side for each NtripSource.

All communication is carried out using Ntrip as described in [3]. As an RTCM standard, Ntrip defines an open non-proprietary protocol. The major characteristics of its stream dissemination technique 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.
- 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.
- 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.

The use of HTTP in Ntrip slightly differs from the HTTP standard. Ntrip utilizes a pragmatic approach that incorporates IP-streaming, similar to techniques employed by Internet radio and video conferencing. The intended constituency for the RTCM information is the wireless mobile user community, which does not use proxy servers. While the protocol works with many proxy servers, their use should be avoided when possible. More detailed information about Ntrip is available on the Web from [4].

IMPLEMENTATION STATUS & PERFORMANCE

As of September 2005, 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. Some implementations duplicate a few hundred incoming raw GNSS data streams or derived products for up to a thousand simultaneously listening clients. At the moment the following formats are in use:

- Raw GNSS receiver data, vendor formats, about 5 kbit/s

- RTK corrections, RTCM formats, about 5 kbit/s
- DGNSS corrections, RTCM formats, about 0.5 kbit/s
- DGNSS corrections, RTCA format, EGNOS and WAAS, about 0.1 kbit/s
- Satellite Orbits, SP3 format, about 6 kbit/s
- RINEX data, about 6 kbit/s
- RTIGS data, SOC format, about 2 kbit/s.

An overview of today's distribution of real-time GNSS data availability in Europe through Ntrip is given in Fig. 2, see [5]. A number of GPS array operators, especially in the public domain, currently considers an upgrade of so far post-processing oriented reference stations to real-time. A list of all known NtripCaster implementations is maintained at [6]

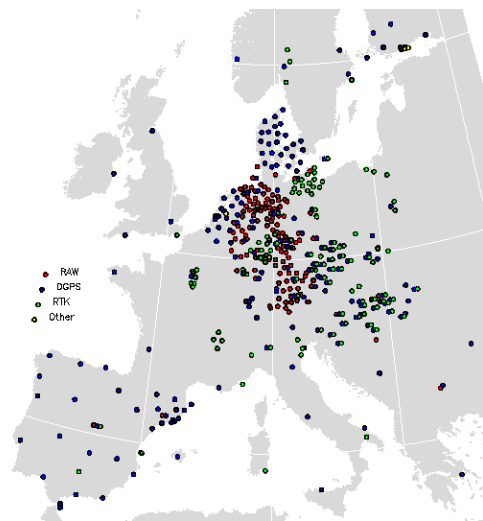


Fig. 2: Ntrip GNSS Data streams in Europe

In order to receive real-time GNSS data streams via Ntrip, a client software is necessary. This may be a standalone 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. It communicates with an NtripCaster for the purpose of user authorization, retrieving a list of active reference stations (source-table) and receiving GNSS data. Numerous NtripClient implementations exist for different operating systems. Some of them – developed within the framework of EUREF-IP – are available from a download Webpage at [4].

The signal travel time of a GNSS data stream can be of decisive importance. An application software on the rover side may need the relevant data most instantaneously. Considerably delayed, missing or irregularly arriving correction data entail a lack of accuracy. The travel time normally poses no problem when exclusive transmission

paths (e.g. AM or FM broadcasters) are used. However, when using the Internet, a DGNSS application may share resources of an Internet Service Provider (ISP) with other applications and the bandwidth cannot be controlled. The question arises in this context as to what extent the usual resources offered by professional ISPs suffice the requirements of real-time positioning and navigation.

Various tests with GNSS correction data in RTCM format have been performed. The communication over Internet and wired as well as wireless phone networks (GSM and packet-switched GPRS) has been analyzed. Latencies less than two seconds are typical for the situation in the Federal Republic of Germany and in Europe [7]. This is considered as so low that no perceptible influence on the achievable positioning accuracy exists.

NTRIP-BASED SERVICE CONCEPTS

One important application of Ntrip are professional Networked DGNSS or RTK services. They provide real-time corrections to reduce positioning errors to less than 1 m or even 1 cm in case of RTK services handling carrier phase observations.

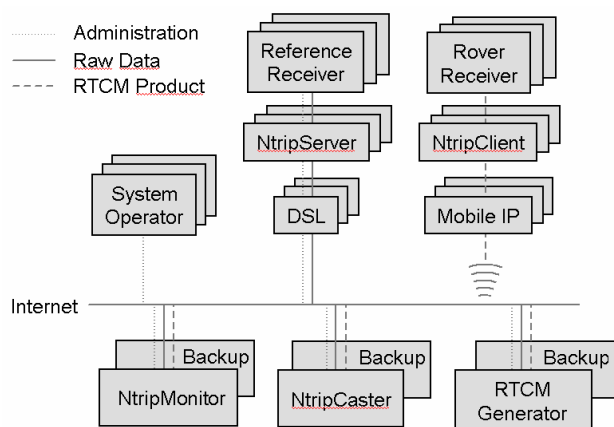


Fig. 3: Professional Ntrip DGNSS Service Concept

With the advent of Ntrip new advantageous concepts for professional services are possible as shown in Fig. 3. Any communication between participating system elements – all spread over the Internet – is based on Ntrip. Autonomous reference stations upload streams via NtripServers and DSL links to an NtripCaster. An RTCM Generator retrieves these streams to derive corrections. These corrections are then transmitted back to the NtripCaster. NtripClients request the RTCM products from the NtripCaster to feed them into a rover receiver.

For professional services a continuous monitoring of all system components is indispensable. The availability of the Internet, of all hardware platforms and software

elements must be validated on a regular basis. The monitoring can simply be carried out by observing all streams disseminated by the NtripCaster. In case of outages the affected stream provider as well as the users can be informed immediately through email or SMS. In the event of an NtripCaster or RTCM Generator failure a backup solution may take over responsibilities straightaway when necessary.

The monitoring can be done by an external software tool on the Internet – independent from any other system component. To operate a service with small data latency and a minimum of outages it is recommendable to run essential hardware components on the premises of a professional ISP. He may guarantee Internet bandwidth with a certain specified level of availability.

NEW APPLICATION AREAS

Real-time positioning and navigation is by far not the only possible application for Ntrip. Various user communities are expected to utilize its potential for science and research as well as for public and commercial services in many GNSS areas. Applications may comprise real-time

- Satellite orbit and clock estimation
- Estimation of global or regional ionosphere, local troposphere, space weather
- Satellite health monitoring
- Interference monitoring
- Geodynamics, natural hazards.

Here, a wide field for generating new real-time GNSS products and services remains today.

Among the current promising Ntrip-based developments is the conversion of WAAS or EGNOS signals to RTCM and the dissemination of results over the Internet. These Space Based Augmentation Systems (SBAS) provide data in RTCA format via geo-synchronous communication satellites. However, receiving SBAS signals is sometimes difficult, e.g. in rough topography, urban canyons, or at northern latitudes and of course requires the availability of present-day equipment. For these problems receiving RTCA corrections as converted to RTCM and broadcasted via Internet is a well-suited alternative. An RTCA2RTCM conversion services is under development at BKG supporting a network of VRS covering Europe and the US. Services like that may also function as a fallback solution for DGNSS services as described in the previous section.

CONCLUSION

The paper introduces the Internet-based RTCM standard Ntrip for disseminating GNSS data. Ntrip is designed to

transfer GNSS data, i.e. in RTCM format via Internet and mobile phone networks. Tests do not show a significant degradation of performance compared to using other transportation media. Ntrip is an international, open standard. Nowadays, various Ntrip hardware and software tools exist, some of them are made available within the framework of EUREF-IP Pilot Project. Due to the widespread resources for wireless Internet access, Ntrip is the conducive and beneficial IP-streaming method of the future.

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