Using the Internet for streaming differential GNSS data to mobile devices

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Abstract - The massive and worldwide growing of Internet communication capacity enables the introduction of new real-time services such as Internet Radio or Internet Video-on-Demand. These services include the data transport via mobile IP-Networks like GSM, GPRS, and UMTS at rapidly decreasing costs. Recent activities focus now on using the global Internet for the real-time collection and exchange of GNSS data. A major purpose is the dissemination of data in support of precise positioning and navigation. This paper describes an http-based technique for streaming GNSS data to mobile users connected to the Internet. It establishes a format called Networked Transport of RTCM via Internet Protocol (Ntrip).

1 Introduction

Global Navigation Satellite Systems (GNSS) provide geographical positioning information from a constellation of satellites in orbit to receivers at sea, on the ground, and in the air. The best known of these systems is the U.S. Global Positioning System (GPS), but the Russian GLONASS system provides a similar service, as will the European Galileo system. Together they are known as Global Navigation Satellite Systems, and they can provide position accuracies in the 10 meter to 15 meter range. Although the satellites have the potential to provide more accurate positions, errors in satellite orbit and clock, ionospheric, tropospheric errors, and receiver clock errors degrade the quality of the satellite signals.

As impressive as GNSS systems are, they do not directly provide accuracies that are good enough to rely on for building works, or ships entering harbors, for example. The satellite signals can be corrected by using a reference station at precisely known locations, which broadcast corrections to GNSS receivers nearby. The two most common methods for real-time relative positioning are called DGNSS (Differential GNSS) and RTK (Real-Time Kinematic). DGNSS uses signal travel time between satellite and receiver to calculate the distance, while RTK also uses a carrier phase and the distance is measured in number of full phase cycles plus a decimal part of one period. The accuracy is 0.5 - 2 meter for DGNSS and 1 - 5 centimeter for RTK [1].

As the use of DGNSS services has grown, governments and commercial service providers have established networks of reference stations. One way to further increase accuracy is to use correction data from multiple reference stations, such as these networks provide. Especially DGNSS has enabled precise navigation not only by ground vehicles, but also ships, and aircraft. It also allows tractors to cross agricultural fields in precisely the same track every time, improving crop yields, and enabling snow plows to operate quickly over roads buried beneath an otherwise trackless snow field. New applications continue to be developed.

So far, differential corrections typically have been broadcast over radio data links (terrestrial or satellite) from reference stations located in precisely known locations, to mobile receivers (rovers) located on the equipment whose position needs to be known. Today, growing packet-switched telecommunication networks like GSM, GPRS, EDGE, or UMTS allow the use of mobile IP-services for precise positioning and navigation. Thus, real-time relative positioning follows other well-established applications which transfer data-streams by IP-packages, such as Internet Radio or Internet Video-on-Demand. Using the common Internet infrastructure leads to a massive cost-reduction for service providers, whereas service users benefit from widely spread communications hardware like PDAs and mobile phones. Compared to Multimedia applications, the bandwidth required for streaming GNSS data is relatively small. As a consequence, the global Internet can easily be used for the real-time collection and exchange of GNSS data, as well as for broadcasting derived differential products.

Introducing the real-time streaming of GNSS data via Internet as a professional service is demanding with respect to network transparency, network security, program stability, access control, remote administration, scalability and client simplicity. This paper introduces the basic principle for the real-time transmission of differential GNSS corrections and discusses several approaces for system and protocol design: Unicast vs. IP-Multicast, TCP vs. UDP, Client/Server vs. Client/Server/Splitter technology. The "Networked Transport of RTCM via Internet Protocol" (Ntrip), a novel HTTP-based technique for streaming GNSS data to mobile clients over the Internet, is presented. It allows simultaneous access of a large number of PDAs, Laptops, or GNSS receivers to a broadcasting host via Mobile IP-Networks. The paper finishes with the description of a real-time monitoring and alarm system and finally summarizes the advantages of Ntrip.

2 Real-time GNSS basic principle

Differential GPS correction data are usually generated on the GPS receiver of a reference station, but can also be derived from networked observations obtained by a number of reference stations. The generated correction data stream is fed into a server which makes the data accessible on the Internet by means of an appropriate protocol (see Fig. 1).

A mobile user gains access to the Internet via mobile phone technology using a client program which forwards the correction data from the server to his GPS receiver. The distance between the reference station and the client rover station is split in two parts. The larger part of the distance consists of a wired Internet connection, while the remaining part may be bridged using wireless mobile phone technology.

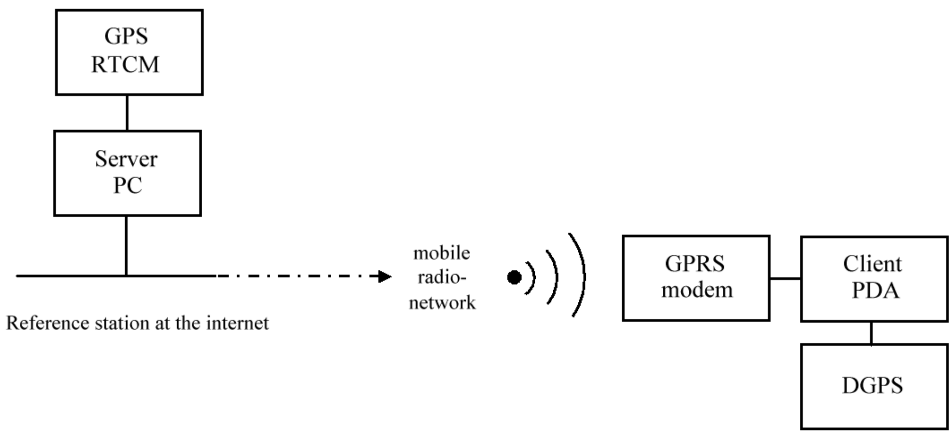

Fig. 1 RTCM data stream on the Internet.

It is up to the users of a DGNSS or RTK service to choose a technique for retrieving correction data from the Internet. The introduction of the „General Packet Radio Service“ (GPRS) as an IP packetswitching service for mobile data communication is of particular importance. GPRS strengthens above all the mobile use of the Internet and is generally considered as the precursor of UTMS. In contrast to GSM, streams are divided into separately transmitted packets, allowing an optimal use of the bandwidth available within a mobile radio cell. Of decisive importance for DGNSS applications is the fact that GPRS allows billing on the basis of the received data volume. This means that the user will no longer pay for the duration of a connection but for the quantity of transferred data. The available transmission capacity is shared between all participants of a radio cell. They occupy the radio line only when packets are transmitted. Compared to GSM, the GPRS or UMTS transmission of DGNSS data leads to massive cost reductions.

The Internet (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. However, the servers required must be tied to the Internet via interconnected broadcasters with sufficient bandwidth. Broadcaster operating expenses mainly depend on the number of simultaneously served clients.

3 Networked Transport of RTCM via Internet Protocol – System design

The flexible Internet Protocol allows different solutions to solve the real-time GNSS data transmission problem. In general it is possible to establish a point-to-point (Unicast) or point-to-multipoint (Multicast) communication, whereas for the transport protocol the reliable TCP (Transmission Control Protocol) or the unreliable UDP (User Datagram Protocol) may be used. However, it is not guaranteed that all transport and communication techniques are globally supported. Using the bandwidth-economic Multicast communication fails, as IP-Multicast is not implemented in current mobile networks like GPRS and UMTS. Using the unreliable UDP transport leads to a lack of flexibility when firewalls and proxyserver are involved. Only the combination of Unicast/TCP guarantees a maximum flexibility and transparency for all different Internet access network techniques. Traditionally the Internet communication is set up on the client/server model. A client program running on an Internet-connected computer requests and receives data from a server running on another Internet-connected computer. For security considerations, a server application - due to its open socket - is susceptible for attacks and should be operated in a sophisticated way. Client applications do not require particular safety considerations.

All considerations lead to a technique called "Networked Transport of RTCM via Internet Protocol" (Ntrip) [2]. As shown in Fig. 2, the Ntrip system consists of

- NtripSources, which generate GNSS data streams,
- NtripServers, which forward a data stream received from an NtripSource,
- NtripCaster, which disseminates streams coming in from NtripServers, and
- NtripClients, which finally access data streams of desired NtripSources.

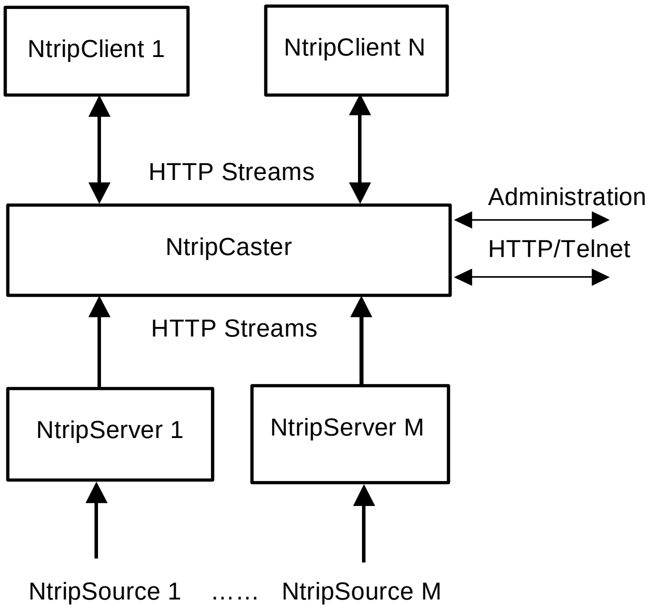

Fig. 2 The Ntrip 1.0 Streaming System.

The NtripServer and NtripClient application are implemented as TCP Clients, enabling simple and safe operation. The NtripCaster is the only TCP Server implementation requiring protection against hacking attacks.

Every NtripSources instance requires a related NtripServer instance. NtripServers define a source-ID called "mountpoint" for every streamed NtripSource. Several NtripClients can access 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. This enables the professional operation of an NtripCaster in a server hosting data center. The administrator running an NtripCaster is responsible for allowing new NtripServers to connect with new NtripSources. The administrator organizes NtripSources through defining the source-IDs (mountpoints).

NtripClients must be able to choose an NtripSource by its mountpoint on the NtripCaster. Therefore a source-table is maintained on the NtripCaster. Each record of this source-table contains parameters describing attributes of a data stream, a network of data streams, or an NtripCaster. Stream attributes (identifier, coordinates, format, navavigation system, mountpoint, etc.) are defined at the NtripServer side for each NtripSource. If an NtripClient sends an invalid or no mountpoint (no or outdated source-table available for the client), the NtripCaster will upload an up-to-date source-table as an HTTP object. Afterwards the NtripClient has a valid source-table and can connect to a GNSS data stream on the NtripCaster. The Ntrip system depends on direct communication between the administrators of NtripCasters and NtripServers (e.g. via email). They specify the parameters characterizing an NtripSource/mountpoint in the source-table.

4 Monitoring System

Due to hardware failure of involved system components and the best-effort character of the Internet, reliable services require a continuous availability and data quality monitoring. The function of an NtripCaster has to be continuously monitored by an alarm system that generates "Notice Advisories to Broadcaster Users" (NABUs). If an NtripCaster is not available from a mobile IP access network, or a specific data stream is unavailable, or transmitted data seam to be corrupt, the monitor system generates a database entry followed by a specific NABU message. A notifications is send out by e-mail to the responsible administrator. An additional message is sent as soon as the problem is soved.

Daily generated Outages Graphics as well as daily and monthly generated Outage Tables can be used to show the overall availability and quality of GNSS data streams from different access networks. The outage information is based on a minute by minute check of distributed trackers in the Internet. They monitor the accessibility, availability and quality of involved GNSS streams at different locations. All results can be transmitted via an encrypted transmission to a redundant monitoring system. The monitoring enables the real-time support for a DGNSS service through call centre telephone hotlines. The real-time database can also be used to include service status information into different service websites, and guarantee a post proof of quality.

5 Conclusions and further work

The global Internet with various access networks like mobile IP (GSM/GPRS/UMTS) enables a user to access specific date independent from his location. From our point of view, it is an ideal suited medium to distribute time dependent GNSS data in real-time from a generating source to clients in the field.

We see Ntrip's Client/Server/Caster approach as the best technical solution to provide real-time streaming of GNSS data as a professional Internet service. This concept and architecture is already widely used in the multimedia domain (Internet radio). The described system can safely be operated behind a firewall while remotely configured and controlled by an administrator. It supports any kind of GNSS data format. Furthermore, an NtripCaster can work as a NtripServer allowing the establishment of combined continental or global networks of cascaded NtripCasters.

A professional server hosting in a data centre is recommended if there is a wide range of customers requesting the service. A server hosting can guarantee a well defined availability at calculable steady costs. The network costs mainly dependent on the defined maximum number of simultaneously listening clients, not on the number of registered clients. The server position can be optimized with respect to the clients access requirements (highly mobile IP availability). A monitoring system is required to identify data source or network failures. Using a real-time monitor helps service providers to detect and correct failures before customers start complaining.

Further developments will extend the NtripCaster/NtripClient communication optional by a Unicast/UDP and Multicast/UDP communication. Especially the Multicast/UDP communication enables a service access via broadcast systems like Digital Video Broadcast (DVB) or Digital Radio Mundial (DRM) for regions, where mobile IP via GPRS or UMTS is not available.

6 References

[1] The Radio Technical Commission for Maritime Services, "New Standard for Networked Transfer of RTCM via Internet Protocol (Ntrip)", *RTCM Paper 234-2004/SC104-PR*, 2004.

[2] Radio Technical Commission for Maritime Services, "Networked Transport of RTCM via Internet Protocol, Version 1.0.," *RTCM Paper 167-203/SC104-315*, 2004.