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GNSS Data Protocols: Choice and Implementation

ABSTRACT

The increasing number of CORS (Continuously Operating Reference Station) installed in Australia and other countries combined with the capacity for worldwide dissemination of CORS data via Internet and wireless networks have highlighted the critical role of GNSS-specific data transmission protocols. This paper reviews the choices available to both CORS network operators and users and analyses the similarities and differences between these protocols. In providing examples, this paper specifically looks at the implementations that CORS network operators in Australia have taken and subsequently the usage by local Australian users.

KEYWORDS: CORS network, protocols, data format, internet, wireless network

1. INTRODUCTION

Data protocol dictates what information can be conveyed from one party to another during communications. Incorrect choice of protocols may result in lack of information needed. It also affects the quality of the communications, i.e. whether it can be carried properly within the required timeframe.

The first section of this paper provides a brief review of RINEX standard and its usage in Australian CORS networks. Although RINEX is not a real-time transmission protocol, it is an important standard, which is widely used for GNSS data exchange. Review on real-time protocols begins with the manufacturer-specific protocols. It is then followed by comparison with non manufacturer-specific, open protocols. Positive and negative points in using either choice are given. We then look at the challenge that CORS network usage pose and how new protocols have emerged to address those challenges. We then conclude by looking at possible future developments for these new protocols.

2. FILE EXCHANGE PROTOCOLS

2.1 RINEX

RINEX (Receiver Independent Exchange Format) was first proposed by the Astronomical Institute of the University of Berne for easy exchange of GPS data during the European campaign EUREF 89 which involved more than 60 GPS receivers of 4 different manufacturers (Gurtner, 2001). Over the years, it has developed into a mature protocol to exchange GNSS data especially between different brands and types of receivers.

Most professional grade GNSS receivers support RINEX by providing utilities to convert from their native binary format to RINEX. Receivers typically do not store data natively in RINEX. One of the reasons is because its ASCII-based nature requires large storage size. Most GNSS processing software support RINEX as this is a convenient method to accommodate data from other brands of receivers. It would take a lot of resources to provide support for other manufacturer's data formats and keeping up with the changes in those formats.

As of writing, Version 2.10 of RINEX is the most widely used. Version 2.11 was released in December 2005 with the main additions being definitions of Galileo satellite system code and frequency numbers and new GPS observables (Gurtner and Estey, 2005). The changes are minor and since Galileo and GPS L2C and L5 are not fully operational yet, most organisations are yet to adopt 2.11. The first draft for the next version of RINEX, Version 3.00, was made available in February 2006 (Gurtner and Estey, 2006).

In Australia, collected data from most CORS networks are available for download over the internet in RINEX, such as from Geoscience Australia's ARGN, NSW Department of Lands' SydNET and Victoria DSE's GPSnet. In some cases, they are provided in Compressed RINEX format (Hatanaka, 1998) to reduce file size and download bandwidth. On average, Compressed RINEX can reduce the file size down to thirty percent of the original RINEX file size. GPSnet in particular has a feature to produce RINEX from a virtual CORS where users are able to request data from virtually any points within GPSnet's coverage.

Because it is designed as a format for file exchange, RINEX is not suitable at all to be used as real-time transmission protocol. Its ASCII-based nature requires a lot of bandwidth and processing power and it does not have any mechanism for integrity check to ensure that data was not corrupted during transmission.

2.2 Manufacturer-Specific File Format

Most GPS receiver manufacturers have their own data file format – typically in binary – which is used by their hardware to log data internally. Discussion of these formats is outside the scope of this paper however as noted above, utilities are usually available from each manufacturer to convert from those formats to RINEX.

3. REAL-TIME TRANSMISSION PROTOCOLS

3.1 Manufacturer-Specific Protocols

As with the case described in 2.2, most manufacturers also have their own data transmission protocols. In some cases, a manufacturer would specify more than one protocol for different purpose or type of receivers. For example, Trimble includes RT17 or TSIP or CMR/CMR+ or a combination of these for different applications. Other known manufacturer protocols are from Leica (LB2), Ashtech (MBEN/PBEN, DBEN), AOA (ConanBinary and TurboBinary), Javad (JPS), Topcon (TPS), u-blox (MBX) and JPL (SOC).

The types of information that they can carry vary widely and are customised to their hardware's capability and requirements. Generally they would also cover data types that are specified for RINEX where applicable. The availability of the specifications to these protocols also varies. Some manufacturers have included the format in their hardware documentations, while some will provide these when requested. Others would treat this as business confidential and would only provide the specifications when an agreement is already in place.

These protocols are normally formatted in binary and hence are quite efficient in bandwidth usage. Some protocols such as Ashtech's MBEN/PBEN or Leica's LB2 can also be formatted in ASCII. In addition to providing data from the receiver, most of these protocols also provide the signalling information to control the receiver and change its settings.

Because the hardware, software and communication protocols are all designed by one party, their features are well integrated, work seamlessly and maximise the features available from both the hardware and software. In addition to this, manufacturers typically provide support to customers who are using their products. These aspects cannot be expected from using open protocols, which will be discussed in the next section.

In the case of CORS networks, it is sometimes impractical and uneconomical to expect all stations within the network to run the same brand or type of receivers. It is often the case that a network would utilise three or four different brands of receiver simultaneously. In this case, the software that controls the stations within the network need to be able to support more than one particular manufacturer protocols. For example, the Trimble GPSNet software being used to control GPSnet in Victoria supports the usage of Leica and Ashtech receivers in the network using their native protocols. Similarly, the Leica Spider software which are currently trialled in GPSnet, SydNET and SunPOZ supports the usage of Trimble and Ashtech receivers.

3.2 Open Protocols

While the definition is indeed rather loose, this section covers protocols, which are supported in more than one brand of receivers with specifications publicly available for implementation. They generally work in a 'one-way' scheme and do not provide method to communicate back to the receiver.

3.2.1 NMEA 0183

The NMEA 0183 Interface Standard is a standard released by the National Marine Electronics Association which defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus (NMEA, 2002). As of writing, Version 3.01, which was released in January 2002, is the latest version of the standard.

A subset of NMEA 0183 messages is dedicated to GPS and widely supported. Most GPS receivers ranging from navigation-grade to geodetic-grade supports the protocol and can output NMEA 0183 messages. These messages are limited to navigation information though and hence do not allow for differential or RTK GPS operation. NMEA 0183 messages are in ASCII format, which is often adopted by receiver manufacturers for their own ASCII-format protocols.

3.2.2 CMR/CMR+

Unlike other protocols discussed in this section, CMR (Compact Measurement Record) was developed by a receiver manufacturer, Trimble Navigation, which was then made public (Talbot, 1996). Since then, other manufacturers such as Leica, Ashtech, NovAtel and Topcon have included support for CMR in their receivers. CMR provided a more bandwidth-efficient alternative to RTCM Version 2 for GPS RTK users. CMR+ is a slightly improved version of CMR that has a less peaked throughput (Talbot, 1997).

Data streams in CMR/CMR+ format are available from CORS networks in Victoria (GPSnet), New South Wales (SydNET) and Queensland (SunPOZ). Network-RTK software such as Trimble GPSnet, Leica Spider and UNSW SIMRSN can also produce streams in CMR/CMR+ format.

3.2.3 BINEX

Perhaps a less known protocols in this section, BINEX, for “BINary Exchange”, is a binary format standard for GPS/GLONASS/SBAS research purposes (UNAVCO, 2006). It has been designed to grow and allow encapsulation of all or most of the information currently allowed for in RINEX and its spin-offs such as IONEX, SP3 and SINEX plus other GNSS-related data and metadata, including next-generation GNSS. BINEX output is supported on some Trimble, Ashtech and Topcon receivers.

BINEX has not been fully defined, with no subrecords for GNSS data proposed yet at the time of writing. There are prototypes available from different parties such as JPL, COSMIC/UCAR, Trimble, and Ashtech however none of them have been proposed for inclusion. As such BINEX are not widely known or used as GNSS data protocols.

3.2.4 RTCM SC-104

The Radio Commission for Maritime Services Special Committee 104 (RTCM SC-104) on GNSS Service has published several recommended standards for use in GNSS data transmission. There are six standards, which have been published by RTCM SC-104 as of writing. They are Differential Navstar GPS Service Version 2.0, Version 2.1, Differential GNSS Version 2.2, Version 2.3, Version 3.0 and Ntrip Version 1.0.

The first standard in list, Version 2.0 only supports Differential GPS. The DGPS accuracy achievable with this version is about 1 meter. Version 2.0 does not contain any carrier phase information so RTK applications are not possible. Version 2.1 which was released in 1993 consists of new message types which allows transmission of carrier phase data and hence RTK applications.

Version 2.2 was published in January 1998 and as the change in its title indicates, include support for the Russian GLONASS satellite navigation system. However, message types 18 to 21 in this version are not fully compatible to the previous version, Version 2.1. The last revision in this release, Version 2.3, was published in 2001 and includes additional message types for antenna types definition (Type 23) and reference point (Type 24).

There are some message types in Version 2, which are reserved for user-specific information such as Type 59. This provision has been utilised by various parties for transmission of data which are not supported by Version 2 such as Network-RTK corrections. An example of this is the RTCM++ format developed by Geo++ (Bagge, 2001).

Version 3.0, which was released in 2004, is a completely new standard with new message types and structures. It was developed as a more efficient alternative to Version 2.x. It is meant to be more efficient, easy to use and more easily adaptable to new situations. The initial release, i.e., Version 3.0, consists primarily of messages designed to support RTK operations. It provides messages that support GPS and GLONASS RTK operations, including code and carrier phase observables, antenna parameters and ancillary system parameters (RTCM, 2004).

Because Version 3.0 is relatively new, a lot of data streams are still provided in Version 2 format. Also, a significant number of user equipments are yet to be updated to support Version 3.0 and hence requires streams in Version 2 format. For example, GPSnet in Victoria provides streams in both Version 2 and Version 3.0 format.

3.3 Bandwidth Comparison

The table below presents some figures for comparison of bandwidth usage using different real-time protocols. The figures are empirical results based on an experiment that the author has done. It should be noted that these figures are not fixed because the number of observations made by the receiver differs from time to time. They are however useful to compare bandwidth usage from different protocols.

Protocols	Bandwidth used
RTCM Version 2.3 (Message 18 and 19)	354 bytes / s
Leica LB2	193 bytes / s
Trimble CMR+	134 bytes / s
RTCM Version 3.0 (Message 1004 – Extended)	129 bytes / s

Table 1. Bandwidth usage comparison between protocols

As can be observed, the new version of RTCM provides significant reduction in bandwidth usage which in the end results in less delay, better performance and reduced traffic cost.

4. NEW INTERNET TRANSMISSION PROTOCOLS

4.1 CORS Network Challenges

In a CORS network, the Network Control Centre needs to disseminate several different GNSS data streams to a multitude of users. Depending on the number of CORS and services available, the number of streams available varies from tens to hundreds. The number of users that need to be served can be even more, ranging in the hundreds or thousands for a very large network.

Methods of accessing real-time GNSS data have also evolved from individual VHF/UHF radio, FM sub-carrier or DGPS beacon to high-speed Internet via wireless mobile or broadband networks. On the CORS network side, fast DSL or fibre-optic lines have replaced slow dial-up link. It is not uncommon now to expect receivers with built-in network port replacing the slow and ageing serial port.

These changes and challenges give rise to a couple of new GNSS-related protocols, Ntrip and RT-IGS, which are discussed in the following section.

4.2 Ntrip

Ntrip (Networked Transport of RTCM via Internet Protocol) is an application-level protocol designed for streaming GNSS data over the Internet (BKG, 2005). It was developed by the Federal Agency for Cartography and Geodesy (BKG), Germany based on an Internet radio streaming server architecture called Icecast. Ntrip is now an RTCM recommended standard. Unlike all the protocols that have been discussed so far, Ntrip is not a GNSS data format. It is a protocol that defines how the data stream is distributed over the Internet.

Despite its name, Ntrip application is not limited to RTCM message format. It can be used to distribute any kind of GNSS data. Ntrip is based on HTTP and uses TCP in the transport layer. It separates between stream providers and users, via the use of a broadcaster, which provides a level of security to stream provides since they do not come into direct contact with Internet and users. It also provides a method for user authentication.

Ntrip has gained wide acceptance across CORS network operators and users. Its client software is available for various operating systems and platforms; Windows, Linux, Windows CE, Palm and Symbian. It is also available as a built-in feature in new receivers from Leica, Trimble, Thales, Sokkia and Topcon.

Many CORS networks in Europe, Asia and America are using Ntrip to distribute data streams to their users. In Australia, both GPSnet in Victoria and SydNET in NSW are known to use Ntrip as their default user authentication and data distribution mechanism.

4.3 RT-IGS

The RT-IGS protocol is a new data format currently under development by the IGS Real-Time Working Group. There are four message types that have been defined; station, observations, ephemeris and surface meteorological data. Unlike other GNSS data format, RT-IGS is unique in that it specifies the message frequency as well; twice per hour for station description, once per second for observations, on issue for ephemeris and once per 5 minute for meteorological data. Except for observation message, the structures for all message types have been defined. At the moment, RT-IGS is using JPL SOC format for their observation message (RT-IGS, 2006).

Unlike Ntrip, which uses TCP, RT-IGS is transmitted using UDP (User Datagram Protocol), which does not guarantee delivery or message order. Therefore it is the responsibility of the user of the messages to validate the quality and quantity of the delivered data. UDP is specified for use in RT-IGS because it is considered to be faster and better for real-time applications over the Internet.

In Australia, Geoscience Australia is actively involved in the RT-IGS Working Group and is streaming data from some of their CORS in RT-IGS format.

Because this protocol is still in its early stage especially in regards to software, a thorough comparison of performance – specifically in terms of latency and reliability – is not yet available.

5. FUTURE DEVELOPMENTS

Many of the protocols covered here are still developing. The next version of RTCM, Version 3.1, is expected to contain new message types that support Network-RTK corrections. Improvements are also being made constantly to Ntrip and RT-IGS. Recently, an effort was made to stream RT-IGS using Ntrip.

It is expected that as real-time applications become more ubiquitous over the Internet, the technology that supports can similarly be utilised for real-time GNSS distributions. Using UDP is the initial step towards that direction. A similar effort can also be made to adapt RTP (Real-time Transport Protocol) and RTSP (Real-time Streaming Protocol). Both of those protocols are currently used to stream real-time video and audio to users.

Multicasting is another developing Internet technology, which can contribute to better delivery of GNSS data. Unlike the currently used unicast, in which a separate copy of data is delivered to each recipient, in multicasting a single packet is addressed to all intended recipient and the network replicates packets only as needed. Multicasting is ideal for distributing a single stream to a large number of users as it greatly reduces the load on the server. However, multicasting requires changes in the network hardware which can be quite costly and hence why it is not widely available yet.

5. CONCLUSIONS

A number of GNSS data protocols have been classified and described in this paper. Their advantages and disadvantages have been presented along with their implementations in Australian setting. Changes in how CORS network operates have resulted in new GNSS data protocols. While they are relatively new, they have changed the way people access GNSS data and enables new real-time products. As they develop, it is expected that they will continue to utilise new technology that becomes available.

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