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Benefits of Telecommunications Technology to GPS Users

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Abstract. For many years, telecommunications technology has assisted GPS users in accomplishing their tasks. Dial-up system over copper phone line enables users to download data from base station at remote locations. Radio modem provides wireless communications link between a base station and a rover to enable surveyors to carry out RTK-surveys. While these techniques are still very much in use, developments in telecommunications technology over the last decade or so has brought more services providing easier use, faster speed and wider coverage. Fast spread of Internet has made TCP/IP protocols ubiquitous resulting in more devices being IP-enabled and Internet-connected. Wireless technology such as GPRS and 3G make better use of bandwidth providing faster speed and better coverage to mobile users. This paper looks at these new emerging technologies and how they could have impact on GPS users. It also discusses recent GPS-related protocols such as Ntrip and RTCM 3.0 which were designed in response to these new developments. Examples will be presented based on local trends, settings and conditions in Australia.

Key words: telecommunications, network, wireless, mobile, protocols, GPS

1 Introduction

While Global Positioning System (GPS) is mainly used for navigation and surveying purposes, many aspects of the system rely on telecommunications technology. All three segments that make up the system, the space segment (a constellation of satellites), the control segment (ground base stations) and the user segment (the signal receiver) are essentially common building blocks to a telecommunications system. Both the space and control segments of GPS are controlled solely by the U.S. Department of Defence. The user segment, the receivers, are designed and produced by various manufacturers and used widely by public. Naturally, this renders the user segment to much innovative development and fast adoption of new technology.

The simplest use of GPS receiver is by using it autonomously, independent of external feedback. This technique typically only gives a positioning accuracy of approximately 15 m. This figure can significantly be improved by using differential measurement techniques, making it more useful for many applications. These techniques require user's receiver to communicate to one or more other receivers to produce measurement with higher accuracy. Traditionally, users would need to setup their own reference receiver and communication link to the rover receiver. In some areas, the reference receivers might be operated as a service by government agencies or commercial companies. For example, in some countries beacon transmitters have been established along the coasts to assist marine crafts in navigation. All these require dedicated communication link to be established separately. Within the last decade however, Internet and mobile networks have grown very rapidly. This provides users with servicing technology with which they can employ differential techniques widely.

2 Protocols

A **protocol** defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event (Kurose and Ross, 2003). Usage of common protocols means compatibility and interoperability. This section looks into several current and new protocols that the author believed will have significant role to GPS users.

2.1 RTCM 3.0

Several different protocols exist for exchange of GPS data but two protocols have become standard, NMEA 0813 and RTCM. As the names suggest, these protocols were produced by the National Marine Electronics Association (NMEA) and Radio Technical Commission for Maritime Services (RTCM). In February 2004, RTCM released the third version of their recommended standards for differential GNSS service commonly referred to as RTCM 3.0.

RTCM 3.0 has been developed as a more efficient alternative to previous versions. It was developed based on requests from service providers and vendors for a new standard that would be more efficient, easy to use and more easily adaptable to new situations. The main complaint was that the parity scheme of Version 2 was wasteful of bandwidth. Another complaint was that the parity was not independent from word to word. Furthermore, even with so many bits devoted to parity, the actual integrity of the message was not as high as it should be. RTCM 3.0 is intended to correct these weaknesses (RTCM, 2004).

RTCM 3.0 consists primarily of messages designed to support real-time kinematic (RTK) operations. The reason for this emphasis is that RTK operation involves broadcasting a lot of information, and thus benefits the most from an efficient data format. RTCM 3.0 provides messages that support GPS and GLONASS RTK operations, including code and carrier phase observables, antenna parameters and ancillary system parameters. However, the format is specifically designed to make it straightforward to accommodate modifications to these systems (e.g., new L2C and L5 signals) and to new systems that are under development (e.g. Galileo).

RTCM 3.0 has been designed using a layered approach adapted from the Open System Interconnection (OSI) standard reference model. A diagram of the OSI standard reference model is shown here.

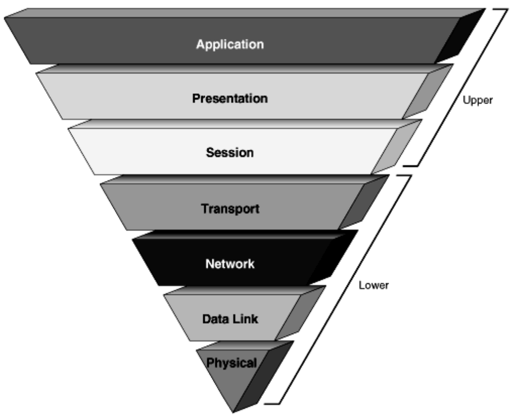

Fig. 1 Seven layers of OSI model (Doyle & Zecker, 1996)

The protocol defines message format on Application, Presentation and Transport layers. The bulk of the document is on the Presentation Layer and describes the message, data elements and data definitions. Implementation on Data Link and Physical layers are left to service providers to determine as they see appropriate to the application.

The higher efficiency of RTCM 3.0 will make it possible to support RTK services with significantly reduced bandwidths. This is especially relevant in wireless and mobile networks where the bandwidth available is much less than that of wired network. The expected performance of this protocol will open ways to more stringent and unique applications of high-accuracy positioning technique. Bock *et al*. (2003) presented a network-based RTK technique in which raw data from several reference stations were aggregated and delivered to users via wireless channel. Such application would benefit tremendously from reduced use of bandwidth.

For wireless link users, who are charged by the amount of bandwidth used, reduced bandwidth means reduced operating cost. For CORS network operators with leased data lines from telecommunications service provider, the reduced bandwidth allows them to provision link with lower data rate and naturally, lower charge from the service provider.

Major GPS manufacturers such as Trimble, Leica and NovAtel have expressed support for RTCM 3.0 by providing firmware upgrade to their products and integrating RTCM 3.0 capability into their current products.

2.2 TCP/IP

The Internet protocols are the world's most popular open-system protocol suite because they can be used to communicate across any set of interconnected networks and are equally well-suited for Local Area Network (LAN) and Wide Area Network (WAN) communications. The Internet protocols consist of a suite of communications protocols, of which the two best known are the Transmission Control Protocol (TCP) and the Internet Protocol (IP).

TCP/IP was first developed in the mid-1970s and has since become the foundation on which the Internet is based. IP occupies the Network Layer on OSI reference model while TCP occupies the Transport Layer. TCP/IP is the foundation on top of which many other Application level protocols such as HTTP and FTP are built.

2.3 Ntrip

Ntrip stands for "Networked Transport of RTCM via Internet Protocol". It is an Application layer level protocol which is used to stream Global Navigation Satellite System (GNSS) data over the Internet. Ntrip is a generic, stateless protocol based on the Hypertext Transfer Protocol (HTTP). The HTTP objects are enhanced to GNSS data streams. Ntrip was built on top of the TCP/IP foundation. It was developed by the Federal Agency for Cartography and Geodesy (known as BKG), Germany.

Ntrip is designed for disseminating 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 such as GSM, GPRS, EDGE or UMTS. Recently, Ntrip has been adopted by RTCM as their recommended standard.

The Ntrip system consists of three software components: NtripClient, NtripServer and NtripCaster. The NtripCaster is the actual HTTP server program while NtripClient and NtripServer act as HTTP clients. In the diagram below, NtripServer receives data from a source (typically a GPS reference receiver) and forward it to the NtripCaster. The NtripCaster acts as a 'switchboard' which connects NtripClients to their required streams.

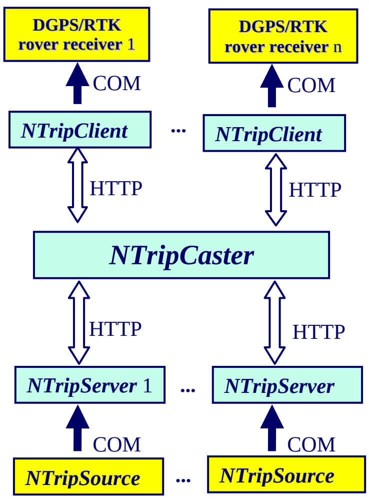

Fig. 2 Connection in an Ntrip system (Weber, 2004)

2.4 Ethernet

The term *Ethernet* refers to the family of Local Area Network (LAN) products covered by the IEEE 802.3 standard that defines what is commonly known as the CSMA/CD (Carrier Sense Multiple Access Collision Detect) protocol. Three data rates are defined in the standard with 10 Mbps (10Base-T Ethernet) and 100 Mbps (Fast Ethernet) being the most common rates at the moment (Cisco Systems, 2003).

Other technologies and protocols have been touted as likely replacements but the market has spoken. Ethernet is currently used for approximately 85 percent of the world's LAN-connected PCs and workstations. Ethernet has survived as the major LAN technology because it is easy to understand, implement, manage and maintain. In provides extensive topological flexibility for network installation. Being a *de facto* standard also implies guaranteed interconnection and operation with other products regardless of manufacturer. Most networked devices have Ethernet port as their standard network connection, from common PC and laptop to the more controversial Internet-enabled fridge and air-conditioner.

3 Applications

3.1 Network Appliance GPS Receivers

A GPS reference receiver typically has three to four serial (RS-232) ports over which it communicates with other devices. In a reference station setup, this receiver is usually connected to a computer which logs measurement data from the receiver which is then distributed to users. This scheme works well for a single base station but has its limitation. As the number of base stations increased, it becomes desirable to control the data centrally. For post-processing use, it is more manageable to have a central data repository compared to multiple computers storing its own set of data. Issues such as user access, fault management, backup, archive and data distribution are all easier to handle with a centralised system. Also, different levels of user needs may mean different type of streams which is currently limited to the physical number of serial ports on the receiver.

For real-time use, network-based solutions such as Network-RTK has proven to be more reliable and offer better performance compared to a single station solution. Network-based solutions require real-time data streams from multiple stations to be aggregated into a central processing system.

A network-enabled GPS receiver provides a good solution to these issues and an elegant way to distribute data and manage the unit. Integration of Ethernet and IP protocols into a GPS receiver brings about the concept of *network appliance* to GPS receivers. With Internet Protocol (IP) as the primary communications method, public domain tools such as web browser and FTP client can be used to configure receiver and access logged data files.

As a network appliance, GPS receiver can provide services to all users attached to the receiver through the network. Different streaming services may be configured on different TCP or UDP ports, for example, with differing data rates or smoothing configurations. To obtain a service, the client has only to connect to a specific port. This allows multiple users to access different streaming services simultaneously.

A network-enabled GPS receiver also provides better remote access to operator. With a web browser, operator can access configurations of the receiver via a webpage without having to connect directly to it. This is especially critical for operators of CORS network where the reference stations are spread over a large area. Previously, to change settings on a GPS reference receiver, operators need to physically connect the computer running the control software to the receiver via serial ports. Obviously, it is not ideal if an operator has to travel hundreds of kilometres only to modify observations rate or other minor settings.

In a CORS network, this concept allows the central server to connect to multiple GPS receivers. With RS-232, the number of data streams is usually limited to the number of physical serial ports available on the computer which is around two to four ports. With Ethernet and IP protocols, it is possible for the server to connect to tens or hundreds of data streams. RS-232 is also much slower compared to Ethernet. RS-232 typically has maximum speed around 115,200 bps whereas Ethernet's speed is typically 10 Mbps – a hundred times faster than RS-232 – with 100 Mbps connection becoming more and more common.

Using Ethernet protocol allows for repeatability, multiple connections and compatibility with higher layer protocols such as TCP/IP or UDP/IP. Being the most popular link layer protocol, Ethernet enables for easy connectivity with other protocols. For example, in SydNET – a real-time permanent GPS network in Sydney, Australia – it allows GPS data to be aggregated to a central server via fibre-optic network which runs on ATM protocol.

As of the time of writing, the author is aware of two network-enabled GPS receivers in the market which are equipped with built-in Ethernet and IP capability. Trimble produces a model called the *NetRS* while Thales Navigation also produces a model called the *iCGRS*.

3.2 Built-in Ntrip

Most parts of Ntrip implementation from BKG have been released under GNU General Public License which means it is open source. This makes it possible for service providers and vendors to incorporate an Ntrip implementation into their products. As of September 2004, implementations of NtripClient are available for PC, Pocket PC PDA and Symbian mobile phone. Some GPS receiver manufacturers such as Trimble and Leica have also added NtripClient and NtripServer implementations into their receiver software.

A list of hardware and software supporting Ntrip is available from BKG's website (http://igs.ifag.de/ntrip_down.htm).

3.3 Using Mobile IP Networks & Wireless Broadband

While RTCM 3.0 addresses bandwidth issue by reducing the message size, mobile networks have also developed in terms of coverage and bandwidth. For example, GSM technology – which gained popularity in Australia and Europe – originally has data capability of 9600 bps. This is only about one-fifth of a 56k dial-up modem. Currently, all GSM networks in Australia have been upgraded with GPRS technology which provides higher data rate and IP network connectivity.

General Packet Radio Service (GPRS) is an upgrade to GSM, providing packet-switching technology and bridging the mobile network to IP network. Unlike GSM, GPRS is an always-on connection where user is charged not by the length of connection but by the amount of data traffic. GPRS provides substantial improvement to data speed with a theoretical limit of up to 170 kbps. GPRS also allows mobile users to access the Internet directly. All GSM networks in Australia, which include Telstra, Optus and Vodafone, support and offer GPRS.

CDMA2000 1X is another technology offered in Australia by Telstra. It offers data rate of around 144 kbps and connectivity to Internet. As with GPRS, users have a choice of PCMCIA access card or a PDA with built-in CDMA capability.

3G technology is another evolution from CDMA with even higher data rate. It claims to provide up to 384 kbps of data rate under ideal condition. So far, only PCMCIA-type card is available to access the service. 3G network is offered in Australia by Hutchison 3G Australia Pty Ltd.

While GPRS, CDMA2000 1X and 3G have all evolved from mobile voice networks, *wireless broadband* started as a service providing broadband connection via radio. Unlike voice networks, this technology is pure IP and is dedicated to data service. Wireless broadband has superior data rate compared to the three technologies mentioned previously. Its maximum speed is at around 1 Mbps which is almost three times that of 3G.

The main disadvantage of wireless broadband network is because they're relatively new their network coverage is nowhere that of voice networks such as GSM and CDMA. The iBurst network for example, is only available in metropolitan area of New South Wales, Queensland and Victoria. Another network, *Unwired*, so far is only available in Sydney. However, it is expected that as this technology gains popularity, their network coverage will expand and cover more areas.

All the technologies mentioned here offer a new and better ways to GPS users to obtain correction service in the field. GSM or CDMA networks, being more ubiquitous in terms of coverage, maybe the choice to many users while those who demand even higher data rate can choose to use personal broadband technology such as *iBurst* or *Unwired* where available.

4 Conclusions

This paper introduced several new technologies which may have significant impact and use to GPS users in the very near future. A new and improved protocol from RTCM allows for reduced bandwidth which means users with slow or limited data link could now exchange data in a standard protocol. Additionally, users now may be able to provision several data streams using the same data link due to the reduced bandwidth. From business point of view, reduced bandwidth means reduced operating cost.

Widespread of Internet and the protocols behind it means a common set of protocols are being adopted. Ethernet and IP protocols have gained wide popularity with many devices adopting it as their standard communication protocols. The concept of GPS receiver as network appliance offer many benefits over the current serial device implementation.

Finally, these protocols allow GPS users to utilise telecommunications networks such as mobile networks to disseminate correction service without having to build new infrastructure. The advent of wireless broadband service with its substantially higher data rate could enable new techniques not possible previously to be used by GPS users.

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