Test Results of an Internet RTK System Based on the NTRIP Protocol

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Abstract

This paper presents test results of an Internet RTK system based on the "Networked Transport of RTCM via Internet Protocol" (NTRIP). The system mainly consists of three components: An Internet server called NtripServer, an Internet broadcaster called NtripCaster, and a mobile client receiver called NtripClient. Both the NtripCaster and the NtripServer used in the tests of this study were developed by the German Federal Agency for Cartography and Geodesy, while a Pocket PC based NtripClient used in the tests of this study was developed by the Finnish Geodetic Institute. Multiple NtripServers receive the RTCM data streams from reference stations and forward them to the NtripCaster from where they are broadcasted over the Internet in real-time. The NtripClient retrieves the data streams from the NtripCaster over a wireless Internet connection (*e.g.* GPRS) and either sends them to the rover receiver where the RTK position is estimated, or performs the RTK positioning inside the client device (*e.g.* a Pocket PC). The Internet-based RTK system provides a multiple-to-multiple solution. Multiple clients can access the same data stream simultaneously, while a single client can access multiple data streams. Therefore, the system can serve many users simultaneously for rigorous network RTK solutions.

Two tests, a static test and a driving test, have been carried out in a suburban area in Helsinki. The static test demonstrated a horizontal positioning accuracy of 3 cm and a vertical positioning accuracy of 8 cm at the level of 95% for a short baseline with an open sky. The driving test was carried out on a route of 18 kilometers in a real driving environment with the driving speed up to 80 kilometers per hour. The driving route covered road segments with open fields or forests on both sides. The vehicle needed to pass under four bridges to complete the whole route. With a GSM data connection, the test results showed that fixed RTK solutions were available for 79% of the driving route, while the percentages for float RTK solutions and navigation solutions (with pseudoranges only) were 12% and 5%, respectively. The float RTK solutions normally occurred during the initial periods before the ambiguities were fixed *e.g.* after the vehicle passed under a bridge. The navigation solutions occurred when the measurements from the reference station were not available. This happens when the data rate of the wireless Internet connection is too low or the connection is totally lost.

In order to assess today's opportunities and limits when combining GNSS positioning and mobile Internet communication techniques, a comparison of the performance of a GSM and a GPRS connection along the same driving route were carried out. The test result indicated that the GSM data connection had a better performance than that of the GRPS connection.

1. Introduction

Real Time Kinematic (RTK) is a carrier phase based relative positioning technology with centimeter-level positioning accuracy in real-time. A conventional RTK system consists of a receiver at a known location (called RTK reference station), a rover receiver, and a radio link for sending data from the reference station to the rover receiver. The communication link between the reference station and the rover receiver plays an essential role for the success of RTK positioning, because the data from the reference station have to arrived at the rover in real-time. A radio link is usually used for the communication task. In addition to its short transmission range, the radio link unfortunately has a few more drawbacks: First,

the transmission range is significantly reduced if there are obstacles located in the path between the reference station and the rover receiver. The signal can be blocked completely by a heavy obstacle *e.g.* a relief topography or even a dense forest. Second, the channel separation between two radio channels are rather narrow, therefore the signal can be easily interfered by other users working in the same frequency band. The interference can reduce the transmission range and quality.

In most conventional RTK receivers, the radio communication link can be replaced by a pair of wireless modems *e.g.* Global System of Mobile communication (GSM) modems. This solution takes advantage of today's almost complete coverage of wireless networks. In this case the distance between the reference station and the rover receiver is not constrained by the communication link. A dedicated channel from the wireless network will be allocated for the link formed by two wireless modems characterizing a point-to-point communication solution.

Using the wireless Internet as a data communication tool for GPS (Global Positioning System) applications is not a new topics in the GPS community (Chen *et al.* 1999; Hada *et al.* 2000; Lee *et al.* 2000; Chen *et al.* 2003 and Liu 2004). Gao *et al.* (2002) have demonstrated that the wireless Internet is a suitable technology for transmitting RTCM (Radio Technical Commission for Maritime services) messages to an RTK system. Their study indicated that the latency of the wireless Internet is in the range of about 1 second and the RTK positioning accuracy is at centimeter level. Bock *et al.* (2003) presented a network-based RTK system using the wireless Internet. In their approach, a client/server architecture was applied. The Internet server aggregated raw data from a network of reference stations, carried our integrity check, and delivered raw data from multiple reference stations to the user via a single TCP(Transport Control Protocol) connection. In their approach, the rigorous network-based RTK positioning was performed inside a Pocket PC-based client.

This paper presents a solution based on the Internet radio technology (see http://www.icecast.org). The solution takes the advantage of the Internet and wireless data communications technologies. The system mainly consists of three components: A stream-server called NtripServer, an Internet broadcaster called NtripCaster, and a mobile client receiver called NtripClient. Both the NtripCaster and the NtripServer used in the test of this study were developed by the German Federal Agency for Cartography and Geodesy (BKG), while a Pocket PC based NtripClient used in the tests of this study was developed by the Finnish Geodetic Institute (FGI).

The data communication link of is divided in two parts: The first part connects the reference stations to the NtripCaster, while the second part connects the NtripClients to the NtripCaster. The first part is operated continuously, while the second part is operated only on users requests. The NtripCaster functions like a "switching center" connecting the users to data streams on-demand. While splitting data streams from various sources in real-time by the NtripCaster, the system provides a multiple-to-multiple communication solution.

2. The Internet-Based RTK System

2.1 The NTRIP Concept

Due to the increased capacity of the Internet, applications which transfer continuous data-streams by IP(Internet Protocol)-packages, such as Internet Radio, have become well-established services. Compared to these applications, the bandwidth required for the transfer of real-time GNSS(Global Navigation Satellite System) data is relatively small. Because wireless or mobile Internet access is available nowadays almost everywhere, the dissemination of GNSS data via IP-streaming becomes an alternative to the usage of conventional terrestrial broadcasting techniques

The BKG, in cooperation with the University of Dortmund, has developed a technique for streaming GNSS data to mobile users. This technique establishes the open none-proprietary "Networked Transport of RTCM via Internet Protocol" (NTRIP), see *Radio Technical Commission for Maritime Services 2003*). Ntrip stands for an application-level transmission protocol based on HTTP(Hypertext Transfer Protocol) where objects are enhanced to data streams. It is designed for disseminating differential corrections or other kinds of GNSS streaming data to stationary or mobile users, allowing simultaneous PC, Laptop, PDA(Personal Digital Assistant), or receiver connections to a broadcasting host. It supports wireless access through Mobile IP Networks like GSM, GPRS(General Packet Radio Serice), EDGE(Enhanced Data rates for Global Evolution), or UMTS(Universal Mobile Telecommunications System). The major characteristics of the concept are:

- Based on the popular HTTP streaming standard; comparatively easy to implement when having limited client and server platform resources available.

- Application not limited to a particular plain or coded stream content; ability to distribute any kind of GNSS data.
- Potential to support mass usage; disseminating hundreds of streams simultaneously for up to thousand users possible when using modern Internet Radio broadcasting software.
- Considering security needs; stream providers and users don't necessarily get into contact, HTTP streaming often not blocked by firewalls or proxyservers protecting Local Area Networks.
- Enables streaming over any fixed-line or Mobile IP network because of using TCP/IP.

The following three software components are part of the protocol implementation: NtripServers, which transfer the data from one or multiple sources to an NtripCaster, the major stream-splitting and broadcasting system component, and NtripClients which receive data of desired sources from there (see Fig. 1).
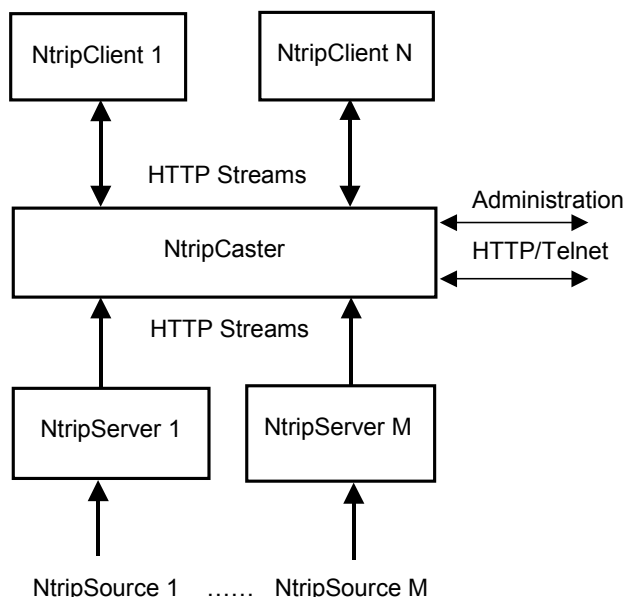

Fig. 1: Ntrip Streaming System

2.2 The NTRIP Components

The NtripServer is used to transfer GNSS data of an NtripSource to the NtripCaster. Before transmitting data using a TCP/IP connection, the NtripServer sends an assignment for a so-called mountpoint that is allocated to the specific data stream. Mountpoints and server passwords are defined by the administrator of the NtripCaster. An NtripServer in its simplest set-up is a PC computer program which sends NtripSource data to the NtripCaster as received *e.g.* via the serial port of a GNSS receiver.

The NtripServer has to connect to the NtripCaster using the IP address and listening Port of the NtripCaster. This means, that the NtripCaster has to be up and running before any source can connect. Before transmitting the GNSS data to the NtripCaster using the TCP/IP connection, the NtripServer has to send an Ntrip server message to get access to a specified mountpoint. This server message is designed as HTTP message "SOURCE", an extension to HTTP 1.1:

SOURCE <password> <mountpoint> <CR><LF>
Source-Agent: NTRIP<product|comment><CR><LF>
<CR><LF>

where *<password>* is the encoder password of the NtripCaster, *<mountpoint>* is the NtripCaster mountpoint for the Source, and *<product|comment>* is information about the source agent. The password is not protected. Like in the HTTP Basic Access Authentications scheme, this assumes that the connection between the client and the server can be regarded as a trusted carrier.

The NtripCaster is basically a HTTP server supporting a subset of HTTP request/response messages. It is adjusted to low bandwidth streaming data (about 0.5 to 5 kbit/s per stream). NtripClient and NtripServer are acting as HTTP clients. The NtripCaster accepts request-messages from either the NtripServer or the NtripClient. Depending on these messages, the NtripCaster decides whether there is streaming data to receive or to send. An NtripServer might be a part of the NtripCaster program. In this case only the capability of receiving NtripClient messages is implemented in the combined NtripServer/NtripCaster.

The NtripCaster maintains a source-table containing records with detailed information characterizing NtripSources, networks of NtripSources, or NtripCasters. The source-table, with its meta-data, is send to an NtripClient on request. Based on source-table information, a client has the possibility to select the data streams of his region containing data in the format he needs. The attributes of data streams, such as identifier, coordinates, format, GNSS system, mountpoint, *etc*., are available from the NtripServer for each reference station.

It is important to understand that IP-streaming for broadcasting purposes is the basis of Internet Radio software. Having the opportunity to use already existing Internet Radio source code resources, and just disseminate GNSS data streams instead of audio data, is a significant advantage when developing an NtripCaster.

An NtripClient is for receiving data from an NtripCaster after sending a request message.

Concerning message format and status code, the NtripClient-NtripCaster communication is fully compatible with HTTP 1.1, but Ntrip uses only nonpersistent connections. A client's request is designed as a HTTP message similar to the Ntrip server message. The client needs to know the mountpoint of the desired data stream. The message for requesting a data stream is:

GET <mountpoint> HTTP/1.0 <CR><LF>
User-Agent: NTRIP<product|comment><CR><LF>
Authorization: Basic <user:password> <CR><LF>
<CR><LF>

where *<mountpoint>* stands for the NtripCaster mountpoint of the requested source, *<product|comment>* is information about the user agent originating the request, and *<user:password>* is a base64-coded string used for authentication and authorization.

2.3 The NTRIP Implementation for EUREF

In June 2002, the IAG Sub-commission for Europe (EUREF) adopted a resolution to disseminate differential corrections in RTCM format via Internet for DGPS positioning and navigation purposes. EUREF's Permanent Network (EPN), comprising approx. 160 continuously operated and continental-wide distributed GNSS reference stations, intends to add an Ntrip-based real-time component to its so fare post-processing oriented services. These activities are known as EUREF-IP (IP for Internet Protocol).

Within the framework of EUREF (see *EUREF-IP*),NtripClient, NtripCaster, and NtripServer software has been developed for various operating systems (see *Ntrip Homepage*). Client software is available for Windows Desktop, Windows CE, PalmOS and Linux platforms. Server programs are available for Windows Desktop and Linux systems. An NtripCaster has been derived from the ICECAST Internet Radio under GNU General Public License. Due to some advantages of Linux systems, the NtripCaster development focused on that but a Windows version may become available later.

EUREF operates a number of NtripCasters today that provide GNSS real-time data in various formats (DGPS and RTK corrections in RTCM format, EGNOS and WAAS data in RTCA and RTCM format, SP3 Ultra-Rapid Orbits, observation data in RINEX format *etc.*). Operated on a high performance DELL Power Edge Linux workstation, BKG's NtripCaster has proven its potential for mass usage. It has been tested under heavy workload when serving up to one million short-time connected DGPS NtripClients per day. While hosted within the premises of a professional Internet Service Provider, the availability of the system over the period of several weeks was

continuously better than 99.5%. The function of BKG's NtripCasters is monitored by an alarm system that generates "Notice Advisories to Broadcaster Users" (NABUs). If a data stream is unavailable for several minutes due to any reason, the monitor system creates a NABU message and sends it by e-mail to the affected stream provider. An additional message is sent when the stream becomes available again. All messages are stored in a NABU Archive. Daily-generated outages graphics and tables show the individual as well as the overall availability of data streams.

EUREF's goal is to establish and maintain a well-distributed network of NtripCaster, all linked with each other. Each implementation may provide access to regional as well as some global data streams. Following this idea, seamless distributed streams are accessible from everywhere with reduced latency while sharing the workload of broadcasting. Besides EUREF with its EPN, a number of public and private institutions has indicated interest in providing DGPS, RTK or raw data over the Internet. Many of them, like the FGI, already make available their data through EUREF's NtripCasters. An overview of today's availability of real-time GNSS data via Ntrip is given in Fig. 2. Furthermore, all distinguished manufacturers of GNSS receivers work together today under the umbrella of RTCM for the standardization of Ntrip and for its integration in their products. RTK software as well as reference station and rover equipment will support the Ntrip protocol in the future.
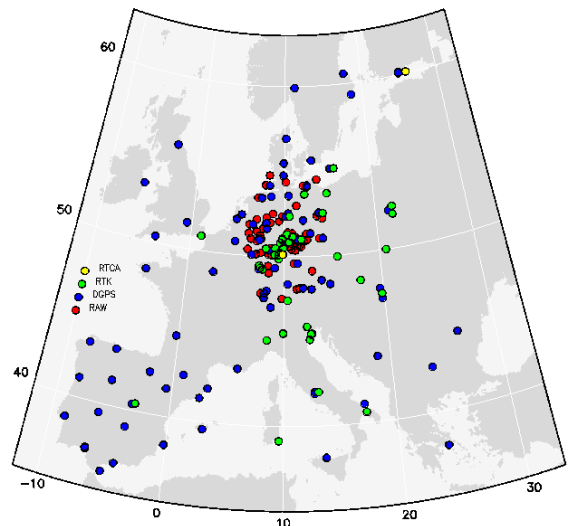

Fig. 2: Real-time GNSS data streams available in Europe, status April 2004

2.4 FGI's NtripClient

An NtripClient is typically a part of an application terminal, *e.g.* a Pocket PC or a mobile phone. It can be standalone software or a component of the application like an RTK processing software. It sends and receives data to and from an NtripCaster for the purpose of user authentication, retrieving the list of active NtripSources (source-table) or receiving raw data from multiple reference stations. It forwards the raw data either to the rover RTK GPS receiver or to a RTK processing software for calculating the position of the rover antenna.

The NtripClient used in this study (see Fig. 3) has been developed by FGI. It is a software component
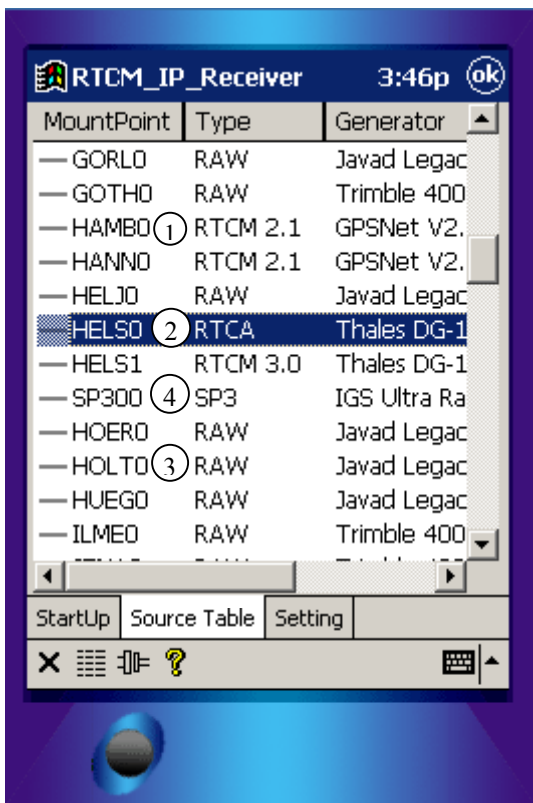

Fig.3. Screen shot of the NtripClient showing different kinds of active data streams including 1)RTCM data streams, 2) RTCA data streams, 3)raw data and 4)IGS ultra-rapid orbits (SP3).

running under the Pocket PC 2003 platform. It is a part of an RTK software under development in FGI. As shown in Fig. 4, the NtripClient mainly consists of:

- A component for sending/receiving data to/from the NtripCaster for the purpose of user authentication, updating the source-table, and receiving NTRIP data streams from the NtripCaster. Principally, the contents of NTRIP streams are not limited to GNSS data. It can be any kind of streaming data, for example digital maps or even real-time traffic information.
- A component for decoding data streams. It is the responsibility of the client to decode and apply the data streams in the NTRIP system.
- A component for utilizing the data streams. Data can be used inside the user terminal *e.g.* for calculating RTK positions, or forwarded to an RTK rover receiver.
- A User Interface (UI) component.

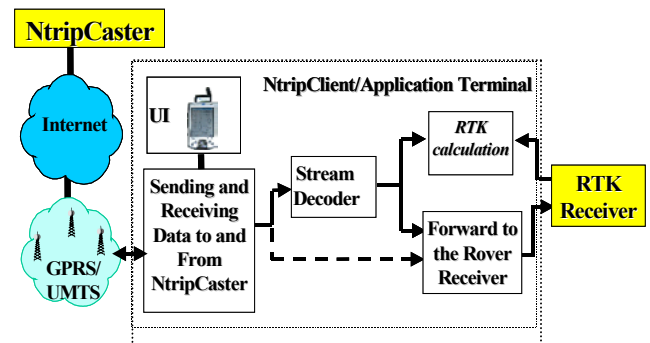Fig. 4. Components of the NtripClient developed by FGI.

3. Ntrip Tests

The objective of the field tests was to examine the system performance, especially the data communication performance, under different situations. Two tests, a static test and a driving test, have been carried out in the suburban area of Helsinki using two Thales ZX-Sensor RTK receivers. A reference station, which was installed on the roof of FGI's office building, sent RTCM corrections to the NtripServer connected to the fixed Internet. The RTCM data stream was sent to the NtripCaster installed in Frankfurt in real-time.

3.1 The Static Test

The static test was carried out on a short baseline of about 10 meters where an open sky was available. The rover receiver was mounted at a site with known coordinates. The Pocket-PC based NtripClient
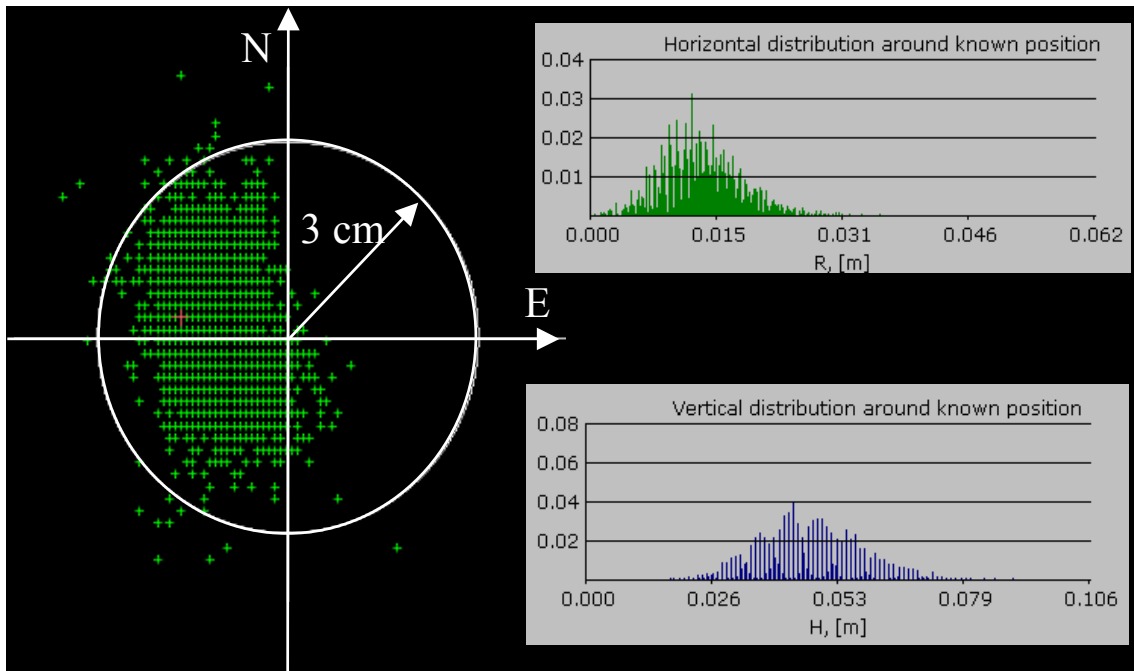
Fig. 5. Results of the static test.

• received the RTCM data stream of the reference station over the wireless Internet using a GPRS modem attached to the Pocket PC, and
• forwarded the RTCM data stream to the rover receiver via the serial port of the Pocket PC.

The RTK calculation was performed inside the rover receiver. The static test demonstrated that the Internet-based RTK system was functioning well. There was no problem with the GPRS wireless Internet connection. The test showed a horizontal positioning accuracy of 3 cm and a vertical positioning accuracy of 8 cm at the level of 95% (see Fig. 5).

3.2 The Driving Test

The major objective of the driving test was to look into the system performance for the following aspects:

• Behavior of the wireless communication link while the rover receiver moves at a speed of up to 80 kilometers per hour, and
• System toleration to an unstable wireless communication link.

Two test scenarios, a GPRS test scenario and a GSM test scenario were carried out on the same route of 18 kilometers in a real driving environment. The drving speed reached up to 80 kilometers per hour. The driving route covered road segments with open fields or forests on both sides. The vehicle

passed under four bridges to complete the whole route. Fig. 6 shows the number of satellites visible along the driving route for the GSM test scanarios. There are 4% of the roads along which the numbers of visible satellites are less than four.
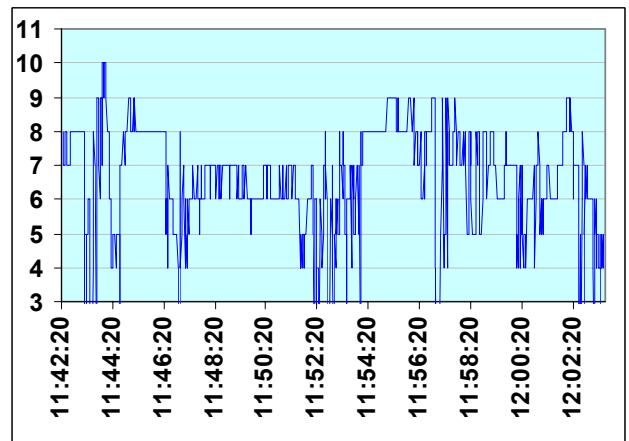

Fig. 6. Number of satellites visible along the driving route.

For the GPRS test scenarios, the wireless service operator provides the Internet access. Therefore, only one GPRS modem installed in the user terminal (Pocket PC) is required.

Theoretically, the GPRS technology can support data rates as high as 171.2 kbps (Bettstetter *et al.* 1999). However, such a data rate is typically not available in practice. The practical data rate available for a GPRS connection depends on

- the current capacity of the GPRS base station. The radio resources of a base station are shared by all GPRS and non-GPRS users. The priority of data calls is typically lower than that of voice calls. Therefore, GPRS users can share only the remaining capacity left by the active voice calls. In short, the more voice calls are active in the base station, the lower data rate is available for the GPRS users,
- the number of GPRS users connected to the same base station. GPRS is a packet switched technology. It allows multiple users to share the current base station data capacity. This means the more the GPRS users are connected to the same base station, the lower data rate is available for each of them,
- the signal strength also affects the data rate. For a connection with a weaker signal, a coding scheme with a lower data rate (9.05 kbps rather than 21.4 kbps) will be employed for a more reliable coding (Bettstetter *et al.* 1999).

A wireless data connection is typically rather stable when the user moves slowly *e.g.* at a walking speed. However, when the user moves at a driving speed as fast as 80 kilometers per hour in an urban or suburban area, the wireless data connection will switch frequently from one base station to another. The factors listed above are also essential for the neighbor base station to which the active data call will be switched. Therefore, it is more difficult to maintain a stable GPRS data communication link when the user moves at a high speed. The performance of the data communication link can be reduced in the ways of slowing down the data rate, blocking the transmission, or even being detached by the network operator (*e.g.* in a case a new voice is calling in and no physical channel is available). All these cases occurred during the driving test along test route.

Fig. 7.a. shows the result of the GPRS test scenario. The green color indicates the locations where the fixed RTK solutions were available, while the yellow color indicates that of the float RTK solutions and the red color indicates that of the navigation solutions (with code measurements only). The percentages for fixed RTK solutions, float RTK solutions and code navigation solutions were 59%, 16% and 22%. There were 3% of the route along which the number of visible satellites were less than four. There were two reasons preventing the rover receiver from providing RTK solutions (fixed or float):

- the wireless data communication link could not deliver the measurements from the reference station to the rover receiver in time,
- the re-initialization time needed for fixing the ambiguities, *e.g.* after the rover receiver passed under a bridge.

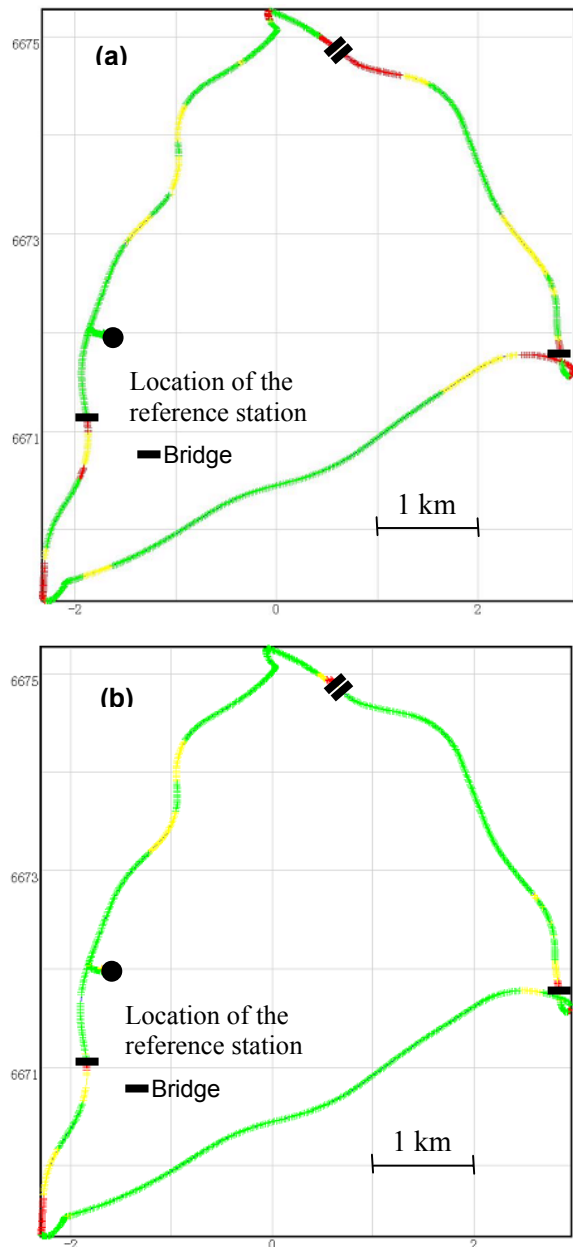The major part of the navigation solutions was caused by the first reason in this case.

Fig.7. RTK positioning results with GPRS and GSM data connections.

For the GMS test scenarios, two GSM modems were required. One modem was installed in the NtripClient, while the other was installed in a computer connected to the Internet for providing an Internet access. Multiple RTCM data streams can be retrieved over the wireless connection formed by

these two GSM modems. As GSM is a circuit-switched technology, the GSM data call has the same priority as a voice call. A dedicated time slot will be allocated for the connection between these two GSM modems. Therefore, it has a higher priority than that of a GPRS connection, and it is not limited by the GPRS capacity in the current base station.

Thus it is easier to maintain the GSM data connection while the users move at a high speed.

Fig. 7b. shows the test result of the GSM test scenario. The percentages for fixed RTK solutions, float RTK solutions and code navigation solutions were 79%, 12% and 5%. It is obviously that the GMS data connection provides a more stable communication link than that of the GPRS connection.

The performance of a GPRS connection is affected by many factors. It normally works fine when the user moves at a low speed *e.g.* walking speed. However it suffers from a decreasing data rate, blocking of transmission and even disconnections by the operator while the user moves at a high speed *e.g.* driving on a highway. The GSM connection showed better performance under such circumstances. Of course, the price (air fee) of the GSM data communication is typically much higher than that of the GPRS connection.

4. Conclusions

This paper introduced an Internet-based RTK system that utilizes the Internet radio technology for disseminating the RTCM and other related data streams based on the NTRIP protocol. The Internet radio technology and the NTRIP protocol form an ideal architecture for a network-based RTK system. The field tests, a static and a driving test, have demonstrated and proven that it is possible to use the Internet Radio technology as a data communication technology for an RTK positioning system. The static test has demonstrated the horizontal positioning accuracy of 3 cm and the vertical positioning accuracy of 8 cm at the level of 95% on a short baseline. The results of comparison tests between GPRS and GSM data connections indicated that the GSM data connection has a better performance when the rover receiver moves at a high speed.

5. References

Bettstetter C., Vögel H. J. and Eberspächer J. (1999). GSM Phase 2+ General Packet Radio Service GPRS: Architecture, Protocols and Air Interface. IEEE Communications Surveys. Vol. 2. no. 3, pp 2-14.

Bock Y., Jonge de P., Honcik D. and Fayman J. (2003). Wireless Instantaneous Network RTK: Positioning and Navigation. Proceedings of ION GPS 2003. Portland OR, 9-12 September, 2003. Pp 1397-1405.

Chen X., Han S., Rizos C. and Goh P.C. (2000). Improving Real-Time Positioning Efficiency Using the Singapore Integrated Multiple Reference Station Network. Proceedings of ION GPS 2000, 19-22 September 2000, Salt Lake City, UT. Pp 9-16.

Chen R, Toran F., and J. Ventura-Traveset (2003). Access to the EGNOS Signal In Space Over Mobile-IP. *GPS Solutions (2003) Vol 7, No. 1, pp 16-22*.

EUREF-IP Real-Time Pilot Project. http://www.epncb.oma.be/_organisation/projects/euref_IP/index.html

Hada H., Sunahara H., Uehara K., Murai J., Petrovski I., Torimoto H., and Kawaguchi S. (1999). New differential and RTK corrections service for mobile users, based on the Internet. Proceedings of ION GPS 1999, Nashville, TN 14-17 September, pp 519-527.

Gao, Y., Liu Z. and Liu Z. Z. (2002). Internet-based Real-time Kinematic Positioning. *GPS Solutions* Vol.5 Nr. 3, pp 61-69.

Lee Y., Kim H., Hong J., Jee G., Lee y., and Park C. (2000). Internet based DGPS for mobile communication users. Proceedings of ION GPS 2000, Salt Lake City, UT, 19-22 September, pp 586-590.

Liu C. George (2004). GPS RTK positioning via Internet-based 3G CDMA2000/1X wireless technology. GPS Solutions, Vol. 7, pp 222-229.

Ntrip Homepage. http://igs.ifag.de/index_ntrip.htm

Radio Technical Commission for Maritime Services (2003). Networked Transport of RTCM via Internet Protocol, Version 1.0. RTCM Paper 167-203/SC104-315, June 2003.