TEST RESULTS OF RTK AND REAL-TIME DGPS CORRECTED OBSERVATIONS BASED ON NTRIP PROTOCOL

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ABSTRACT:

For many years, real-time DGPS and RTK correction data distribution have been providing GPS users a means to accomplish their tasks with high accuracy positioning in real-time. Dial-up systems over phone line or local area network (LAN) enable users to download data from base stations at remote locations. Radio modems provides wireless communication links between a base station and a rover to enable surveyors to carry out real-time DGPS and RTK-surveys. While these techniques are still very much in use,the developments in telecommunication technology over the last decade or so has brought more services providing easier use, faster speed, and wider coverage of GNSS data distributions via Internet. NTRIP, or "Networked Transport of RTCM via Internet Protocol" developed by the Federal Agency for Cartography and Geodesy of Germany, enabling the DGPS or RTK correction data is streamed via Internet using GPRS or other future technologies. This paper discusses the technical basics of NTRIP and illustrates the test results of real-time DGPS and RTK observations based on NTRIP protocol. This study was carried out with three different GPS receivers; high, medium and low accurate, which classified according to the receiver accuracy performance and cost. It has been found that NTRIP is a cost effective, secure and reliable alternative to replace conventional RTK and real-time DGPS correction streaming techniques.

1. INTRODUCTION

Global Positioning System (GPS) developed and maintained by the US Department of Defense, enables positioning and navigation in three dimensions, which are the primary functions of GPS. It provides two levels of broadcast service to the GPS user, the standard positioning service (SPS) and the precise positioning service (PPS). SPS is a positioning and timing service available world-wide to all GPS users. It is transmitted by each of the twenty four satellites in the GPS constellation as a microwave carrier signal of frequency 1575.42 MHz (designated L1). This signal contains the coarse acquisition code (C/A) and a navigation data message. The navigation data message consists of clock data parameters and their relationship to GPS time, satellite status and ephemeris messages, and almanac data that describe the satellite orbits over time. PPS is a higher accuracy positioning, velocity and timing service, also available world-wide with a restricted access; authorized users of United States and related military users have access with a specially designed receiver. PPS is broadcast on both the L1 and L2 (1227.60 MHz) frequencies. It contains the precise code (P) or its encrypted equivalent, the Y-code. All SPS receivers which are presently available could be classified into three groups according to their accuracy performance and cost. It could be enlisted as follows;

- High accurate; code (C/A) and carrier (L1/L2) dual frequency GPS receivers with differential capability. 1 mm to 1 cm accuracy. High cost receivers.
- Medium accurate; code (C/A) and carrier (L1) single frequency GPS receivers with differential capability.1 m to 10 m accuracy. Medium cost receivers.
- Low accurate; code (C/A) receivers. Hand held low cost GPS receivers, which claim 5 m to 15 m horizontally.

The atmospheric and ionosphere delay, signal noise, clock drift and errors due to ephemeris data highly diminish the observation accuracies with GPS receiver in an independent manner. The differential GPS (DGPS) technique allows GPS users to achieve the precision levels required considerably eliminating the said receiver independent errors. Post-processing DGPS, real-time DGPS / real-time kinematics (RTK), wide area argumentation systems (WAAS), local area argumentation systems (LAAS) and virtual reference station (VRS) are some of the existing techniques of correcting GPS observations. Most of these existing real-time correction methods are based on information sent between the measurement equipment and permanent reference stations referred to as base stations. For many years DGPS or RTK correction data distributions have been carried out by using very high frequency (VHF) radio signal transmitter or dial-up system over the phone. Even though the radio/mobile communication technology got dramatically improved in last few years, still there are significant numbers of difficulties and drawbacks in using the aforementioned techniques.

With the increase of available bandwidth of Internet, researchers are now exploring the use of Internet as an alternative for transmitting GPS data for real-time or near real-time correction of GPS observations. As a result, a new technique using Internet for streaming RTK/DGPS corrections allowing precise positioning and navigation was announced in late 2004, under the name of “Networked Transport of RTCM via Internet Protocol (NTRIP)”. The development of this new

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technique was carried out by the Federal Agency for Cartography and Geodesy, Germany (BKG). Development of systems with mobile Internet access facilities through general packet radio service (GPRS) and global system for mobile communication (GSM), provides a fast and reliable method for distributing row GPS data or feeding real-time differential corrections (DGPS/RTK) to a GPS receiver at any area which come under the coverage of a mobile telephone network. The radio technical commission for maritime services (RTCM), standardized NTRIP as the world standard for GNSS data streaming through Internet in November 2004. (RTCM Paper 234-2004/SC104-PR)

1.1 Real-time DGPS and RTK with NTRIP Protocol (version 1.0), (Source RTCM Documentation Version 1.0)

NTRIP is a generic, stateless protocol based on the hypertext transfer protocol (HTTP/1.1) and HTTP objects are extended to GPS data streams. The system is implemented through three applications, namely, NTRIP Server, NTRIP Client and NTRIP Caster. The NTRIP Server and NTRIP Client function, technically, as HTTP clients, while the NTRIP Caster acts as the true HTTP server. NTRIP is meant to be an open non-proprietary protocol for the real time streaming of DGPS or RTK corrections to mobile receivers.

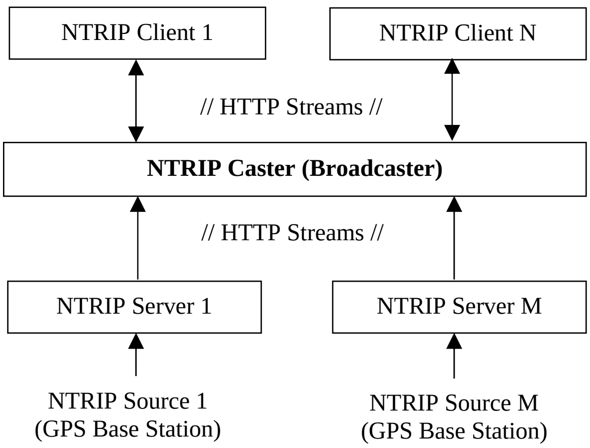

Figure 1. NTRIP Components (Source: RTCM Documentation Version 1.0)

The typical NTRIP data streaming flowchart is shown in Figure 1 to illustrate a general case of NTRIP component setup with M number of NTRIP sources and N number of clients uploading and accessing data streams symultaniously from the NTRIP Caster or the data distributer.

NTRIP Sources: provide continuous GPS data (e.g. RTCM 2.0, RTCM 3.0, and row) as data streams. A single data source represents the data generated by a specific GPS reference station (base). Each GPS data source is identified by its unique ID called mount-point. **NTRIP Server:** transfers GPS data generated by an NTRIP Source to the NTRIP Caster. **NTRIP Caster:** is basically an HTTP server supporting a subset of HTTP request/response messages and adjusted to low-bandwidth streaming data from 50 up to 500 Bytes/sec per-stream. The NTRIP Caster administrator organizes all available NTRIP Sources and defines all source IDs (mount-points). **NTRIP Client:** will be accepted and receive data from an NTRIP Caster, provided that a correct request message is sent (TCP connection to the specified NTRIP Caster IP and listening Port). With respect to the message format and status code, the communication between NTRIP Client and NTRIP Caster is fully compatible to HTTP 1.1. NTRIP Clients choose an NTRIP Source (mount-point) with reference to the source table information (Identifier) provide by NTRIP Caster.

2. FIELD TESTS

Field tests were carried out from March to June, 2006 with the collaboration of the Geoinformatics Center (GIC) of the Asian Institute of Technology and the Ultimate Positioning Co., Ltd, Thailand.

One of the main objectives of the field tests was to determine the accuracy of real-time DGPS and RTK observations which could be achieved by the application of NTRIP technology. Investigating the effectiveness of NTRIP technology over the conventional DGPS and RTK observation techniques was another objective.

In order to generalize the experiment, three different GPS receivers representing high, medium and low accurate categories were used, viz. SOKKIA GSR2600 dual frequency (L1/L2), Trimble ProXR single frequency (L1), and Garmin eTrex hand held GPS receivers respectively (Figure 2). A pocket PC with GPRS connection was used to establish the real-time communication with NTRIP Caster. VHF radio signal transmitter and VHF radio signal receiving antenna were also used in the base station and in the field respectively as the conventional means of correcting the observed data.

Field experiments with NTRIP were executed after the establishing connections with the GPS base station at GIC. It operates with two NTRIP Servers, and uploads raw and DGPS data to the NTRIP caster (IP: 203.159.29.16 :80) already established at GIC. This NTRIP Caster (Standard NTRIP Caster Version 1.0) or the GPS data broadcaster has the possibility to get connected by about 100 users simultaneously to access real-time streaming GPS data. The GPS base station at GIC was temporally updated with a dual frequency (L1/L2) GPS receiver, in order to receive RTK streaming for this field experiment.

Field work was so planned to execute the tests with seven different base line distances, the distance from reference station to the field observation station, of about 4, 16, 30, 230, 290, 360 and 520 km. For the convenience of presenting the results, base line distances are represented as 5, 15, 30, 200, 300, 400 and 500 km respectively. Locations having permanent ground control stations as shown in the Figure 2 and which were established by the Department of Land, Thailand, were chosen as the observation sites. These ground control points are well constructed monuments and attributed with coordinates of very high accuracy by the Department of Land.

a) b) c)

Figure 2. a) SOKKIA GSR2600 dual frequency (L1/L2) receiver and radio signal receiving antenna, b) Trimble ProXR GPS receiver c) Pocket PC with GPRS and Garmin eTrex low-cost GPS receiver.

Base Line	High - Accurate (L1/L2 Receiver)		Medium - Accurate (L1 Receiver)		Low - Accurate (Hand-held Receiver)	
	RTK with VHF	RTK with NTRIP	DGPS (Post -Processing)	DGPS with NRTIP	Uncorrected	DGPS with NTRIP
5km	0.161 m	0.162 m	0.586 m	0.532 m	4.37 m	3.36 m
15km	0.160 m	0.152 m	0.496 m	0.621 m	2.68 m	1.84 m
30km	0.160 m	0.158 m	0.416 m	0.340 m	2.21 m	1.96 m
200km	-	-	0.775 m	0.782 m	2.29 m	1.83 m

Table 1. Average positional accuracy comparison for three different GPS receivers

3. ACCURACY COMPARISONS

Field tests were carried out with the apparatus described previously through which following data were collected in order to have an accuracy comparison.

- Static RTK corrected observations by using dual frequency (L1/L2), SOKKIA GSR2600 GPS receiver, (high-accurate)
  - i) RTK correction transmitted with VHF radio signal.
  - ii) RTK correction transmitted with NTRIP.

- Static observations with single frequency (L1) , Trimble ProXR GPS receiver, (medium-accurate)
  - i) DGPS corrected observations with post-processing.
  - ii) Real-Time DGPS corrected observations with NTRIP.

- Static observations with C/A cord, Garmin eTrex hand-held GPS receiver, (low-accurate)
  - i) Uncorrected (raw) observations
  - ii) Observations with NTRIP.

Table 1 gives the average positional accuracies obtained by employing high, medium, and low accurate GPS receivers for 4 study sites. The accuracies were calculated by averaging the magnitude of the absolute positional error of the individual observation record at 5 seconds intervals. The absolute positional error is assumed as the difference of the observed and the absolute test site coordinate. More than 20 minutes of observations were carried out at all the stations with each type of GPS receiver.

Accuracies obtained by using the Medium accurate, single frequency (L1) GPS receiver are also listed in Table 1. The post-processing and real-time DGPS corrected observations of the positional accuracies compares well. It is encouraging to note that by carrying field surveys with DGPS-NTRIP technique it is possible to obtain real-time data which are comparable to post-processed data. Further, the average positional accuracy for each observation remains at sub-meter level and varies depending on the observation site and satellite conditions. It could be stated, therefore, that the achievable accuracy is independent of the type of correction whether post-processing or real-time.

Accuracy levels of the observations made using a low accurate hand-held Garmin eTrex GPS receiver and the same corrected through real-time DGPS correction with NTRIP technique is given in the columns at the right extreme of Table 1. It is seen from Table 1 that the corrected observations have achieved an accuracy of about 1.85 m. However, that pertaining to a base line distance of 5 km is found to be 3.36 m. This may be due to poor resection of satellite signals, interference by surrounding obstructions, etc. It was identified that further accuracy enhancements were restricted due to GPS receivers' hardware and software configurations.

The positional accuracy comparisons made in Table 1 and the descriptions made above are justifying that the NTRIP technique is the most cost effective, reliable and accurate method for RTK/real-time DGPS observations made through the GPS receivers referred to. However, the average positional accuracies with the NTRIP technique were not always identical with those obtained after post-processing. Therefore, further analyses of real-time DGPS observations were also carried out to identify the limitations of real-time accuracy enhancement with NTRIP technique including the observations with base line distances of 300 km, 400 km and 500 km. The real-time and post-processed DGPS corrected observation accuracies were compared as shown in the Figure 3 to identify the effect of base line distance on real-time correction. The results depicts that the base line distance is an independent factor as far as the real-time DGPS correction with NTRIP is concerned. The average observation error, as could be seen from Figure 3, is less than or approximately 0.5 m for all the stations except for the base line distance of 200 km. This deviation may be due to the poor satellite resection because of the obstructions at the site.

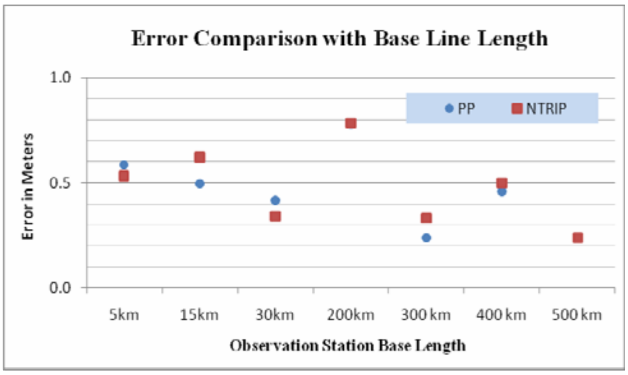

Figure 3. NTRIP and post-process DGPS corrected observation average accuracies.

Position Dilution of Precision (PDOP) is a measure of the geometrical strength of GPS satellite configuration. This was identified as a common accuracy diminishing factor for any real-time or post-processed DGPS observations. The effect of PDOP on the accuracy enhancement was, therefore, tested in addition. However, according to Figure 4 it can be seen that, in the PDOP range of 2.0 to 9.0, there is no significant variation of positional accuracy with the PDOP change. Present, if there are no artificial obstructions effecting on satellite resection then observations with less than 5.0 PDOP values are always achievable due to the wide availability of the GPS satellites. Hence, PDOP is not a significant factor to be considered in accuracy enhancement of real-time DGPS observations with NTRIP technique.

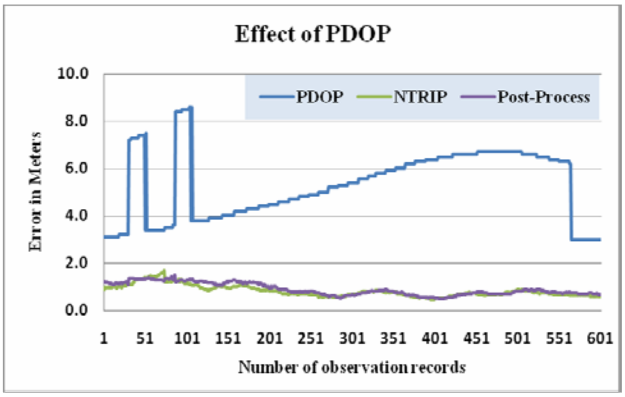

Figure 4. Effect of PDOP for the positional Accuracy *(No Units for PDOP)

A detailed comparison of positional error for real-time and post-processed DGPS observations is illustrated in Figure 5. A significantly higher value of error in real-time corrected observations could be seen after about the 240th observation record. These sudden deviations of the accuracies for NTRIP technique might have occurred due to the delay of Internet communication because of high Internet traffic or due to the receiver real-time processing limitations. It should, however, be noted that the receiver used for the observations shown in Figure 5 was a medium-accurate GPS receiver and hence, the causal factor for the above anomaly may be the delay of real-time correction instead of the receiver processing limitations. It could be taken, thereof, that the Internet traffic is the most significant factor that diminishes the accuracy when NTRIP is used as the real-time correction method.

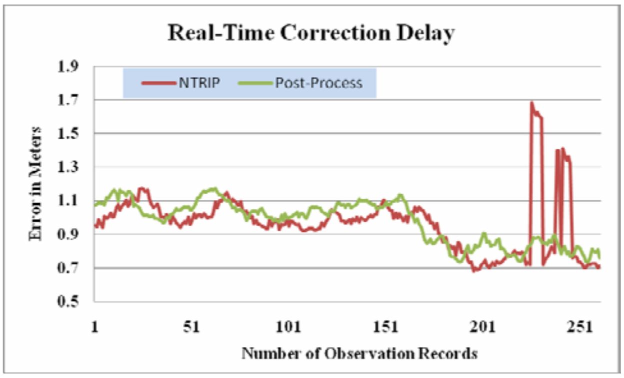

Figure 5. DGPS Corrected Observations Positional Error comparison

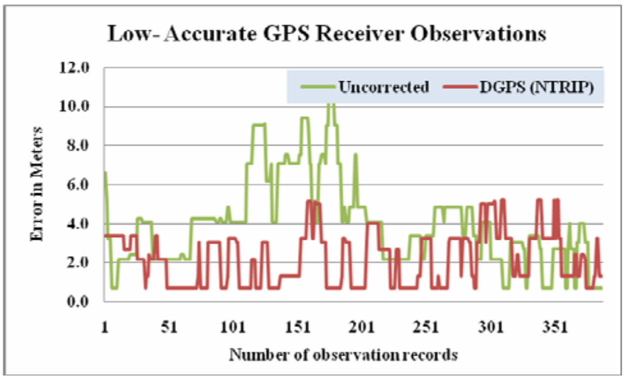

Figure 6. Real-time DGPS Corrected and Uncorrected Observations Positional Error comparison

A detail error comparison for a low-accurate GPS receiver observation records is depicted in Figure 6. According to the Figure, most of the DGPS corrected observations are seen to be recorded with enhanced accuracy compared to the uncorrected observations. However, the error plots are not smooth curves compared to those obtained by the use of a medium-accurate GPS receiver. These errors are attributed to receiver processing limitations of the low-accurate (low-cost) GPS receivers. Unusually, few DGPS corrected observations are seen to be recorded with a lower accuracy (higher error) than the uncorrected observations. These are considered to be blunders made by the GPS receiver processing chipset. For low accurate GPS receivers, hence, the dominant accuracy diminishing factors are the limitations posed by the hardware and software configurations.

4. CONCLUSIONS

A field experiment was carried out to determine the accuracy of real-time DGPS and RTK observations which could be achieved by the application of NTRIP technique; three different GPS receivers representing high, medium, and low accurate categories were used. Test base line distances ranged from 5 km to 500 km.

Results indicate that the accuracies obtained using the NTRIP technique and those obtained after post-processed DGPS data compare very well. It could be concluded, therefore, that NTRIP is the most cost effective RTK and real-time DGPS correction streaming technique with a large coverage and usage. It also provides a more reliable and safe method of RTCM correction streaming compared to transmitting the same with radio signals. Random errors due to high internet traffic and receiver processing limitations are found to be the main accuracy diminishing factors of the real-time DGPS correction. Therefore, it is recommended that a correction approach including a real-time filtering technique to remove these random errors be developed. Obviously, the advantages disclosed by this research study along with the development of high speed mobile Internet facilities would lead NTRIP to a new generation of real-time differential GPS.

In addition, NTRIP provides new concepts of GNSS data sharing technique leading to many different new GPS applications such as the concept of "Global Real-Time Network of GNSS Reference Stations". This concept may lead to many research activates globally due to the availability of real-time GNSS reference station data all over the world. NTRIP provides potentially a great amount of benefits, not only in global applications but also in regional, local or even individual applications such as data for deriving real-time satellite orbital parameters and satellite clock errors, local and global real-time ionosphere modeling and real-time disaster predictions such as earthquakes and tsunamis. Moreover, other local RTK or DGPS applications, such as accurate field surveying (Cadastre Mapping), GIS data collection, mobile mapping, navigation and etc, could avail the NTRIP technique to provide great benefits for the users as well as stream providers.

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