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Designing a GPS Receiver Network with GNSS Algorithm for Accuracy and Safety

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ABSTRACT

Base on a generalized GPS/GNSS software package which is named as GAFAS (GNSS Algorithm For Accuracy And Safety), a receiver network is designed and implemented over the wireless Internet. The designed receiver network consists of a single broadcaster, several servers, and bulks of clients. In the designed configuration, each server is paired with at least one high-quality dual-frequency receiver and provides reference information to the broadcaster. Each client is paired with a single or dual-frequency receiver and computes accurate real-time kinematic position estimates by the GAFAS. The broadcaster connects all the servers and clients in the network, authenticates each server and client, and distributes measured or processed information to the clients. Several key results will be presented to show the functionality, accuracy, and reliability of the introduced GPS receiver network that is under the development.

KEYWORDS: GNSS, receiver, wireless, network, algorithm

1. INTRODUCTION

In the early days of GPS service to civilian users, the positioning accuracy of the single point positioning (SPP) was several tens of meters. However, by the development of various classical differential GPS (DGPS) methods, positioning accuracy was improved to several meters. In the classical DGPS methods, correction information was transmitted by low power transmission media. They were capable of only the one-to-one communication between a reference station and a mobile station and had a difficulty in long-range transmission.

To solve the problems, large scale navigation systems were developed utilizing geo-stationary satellites or ground antennae to transmit correction information. Three well-known examples of these systems are the Satellite Based Augmentation System (SBAS), the Ground Based Augmentation System (GBAS), and the Ground based Regional Augmentation System (GRAS). Since the advent of these systems, it has been possible to communicate with one reference and multiple mobile stations. It also has been possible to increase transmission range of correction information. However, these systems required expenses to install and operate communication satellites or large scale ground antennas. Also, because transmission methods are one-way, it was not easy to monitor status of each mobile receiver.

Recently, the utilization of the wired and wireless Internet technologies in improving GPS/GNSS capabilities is actively studied. (I. S. Cho and J. H. Yim, 2002; M. G. Soares *et al.*, 2003; G. Weber *et al.*, 2004) When the Internet is utilized as the transmission media for differential GPS/GNSS, transmission range becomes nearly unlimited. Also, both the forward transmission of correction data and the reverse reception of mobile data for status monitoring become possible because the flexible two-way communication is easy to implement.

To provide accurate and reliable position information to diverse mobile users in real-time, this paper introduces a receiver network built on a generalized GPS/GNSS software package that is named as GAFAS (GNSS Algorithm For Accuracy And Safety). (H. K. Lee and J. Y. Sim, 2006) The advantage of the GAFAS compared with other GPS/GNSS software packages is that it emphases on advanced fault detection and isolation capabilities for real-time kinematic applications.

The designed receiver network consists of a single broadcaster, several servers, and many clients. In the designed network, each server is paired with at least one high-quality dual-frequency receiver and provides reference information to the broadcaster after an authentication process. Each client is paired with a mobile device connected to a single or dual-frequency receiver. The broadcaster connects all the servers and clients in the network, authenticates each server and client, and distributes measured or processed information to the clients. If connected to the network, each client can compute accurate and reliable position estimates in real-time due to the characteristics of the GAFAS.

2. GNSS ALGORITHM FOR ACCURACY AND SAFETY

Nowadays, the application of GPS/GNSS technology is already among every routines. Furthermore, the diversity of GPS/GNSS applications become more and more and cannot be estimated exactly. At best, it can be anticipated that

i) The cost of the GPS/GNSS hardware become less and less
ii) The real-time capability become more important than the post-processing capability in

more and more application areas
iii) The diversity of the devices that utilize the GPS/GNSS technology become more and more.
iv) Most of the devices will be mobile (kinematic)
v) Most of the devices will be connected by networks

Figure 1 shows a possible sketch on the configuration of the future GPS/GNSS utilization as described above.

As can be seen by the client types in Figure 1, real-time kinematic positioning (RTK) would cover considerable portion of the future GPS/GNSS application areas. In addition, the intelligence of the GPS/GNSS software would be desirable if the complex signal environments of the satellite navigation signals are considered. To enable the accurate and reliable processing of the GPS/GNSS measurements in real-time kinematic applications, a generalized GPS/GNSS software package named as GAFAS has been developed. GAFAS is the abbreviation of the GNSS Algorithm For Accuracy and Safety. (H. K. Lee and J. Y. Sim, 2006)

The GAFAS consists of approximately 200 subroutines for fault detection, fault isolation, RTK position estimation, data interfaces, multi-frequency measurement combinations, integer ambiguity resolution, mode selections for real-time, post processing, and pure software simulations as shown in Figure 2.

The GAFAS software package is purposed to produce accurate and reliable float solutions in RTK applications in the presence of multipath errors, soft faults, and frequent changes in visible satellites. The GAFAS software package is designed by the structure shown in Figure 3. As shown in Figure 3, the GAFAS utilizes multiple channelwise fault detectors, a channel selector, and the position-domain Hatch filter for good estimation and FDI (fault detection and isolation) capabilities. (H. K. Lee *et al.*, 2002; H. K. Lee *et al.*, 2003; H. K. Lee *et al.*, 2004; H. K. Lee *et al.*, 2005)

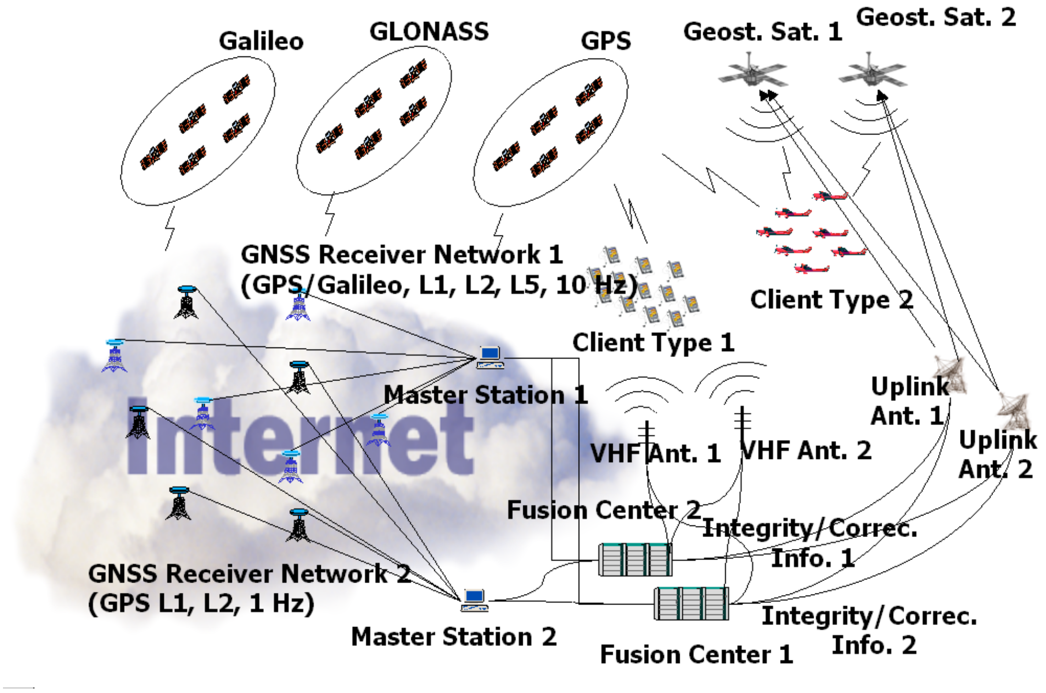

Figure 1. Configuration of the future GPS/GNSS utilization

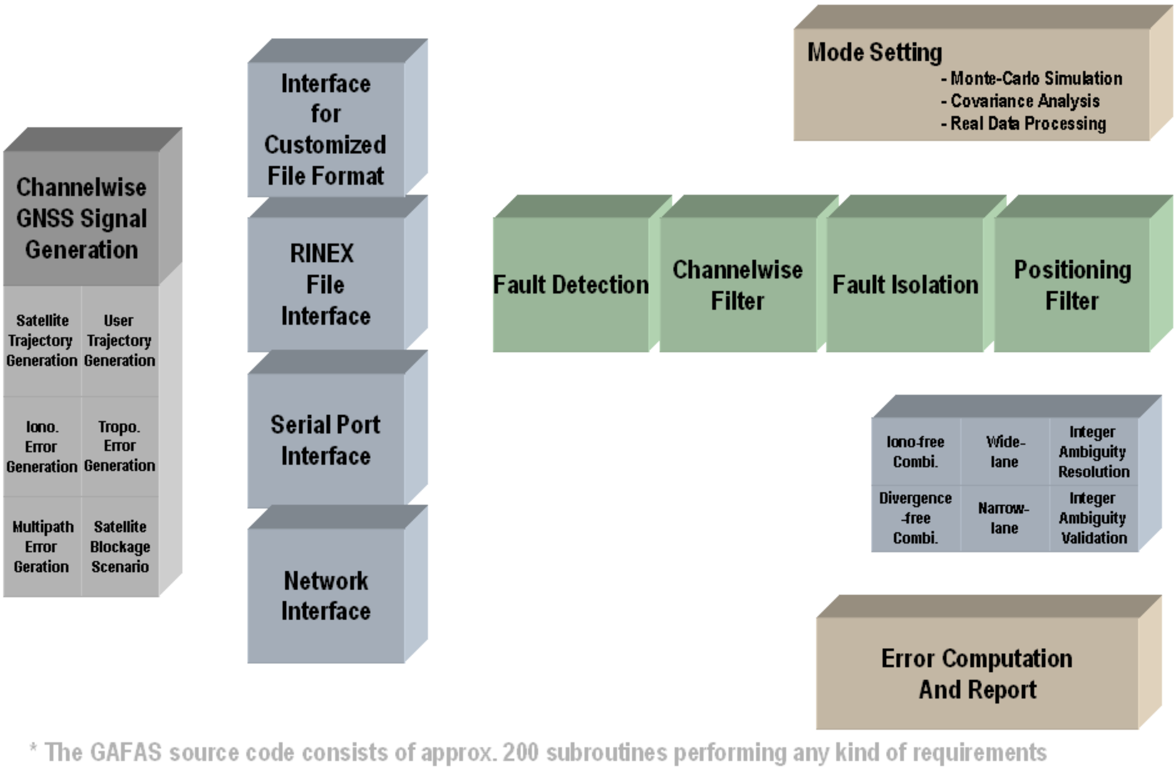

Figure 2. Software modules consisting GAFAS (GNSS Algorithm For Accuracy and Safety)

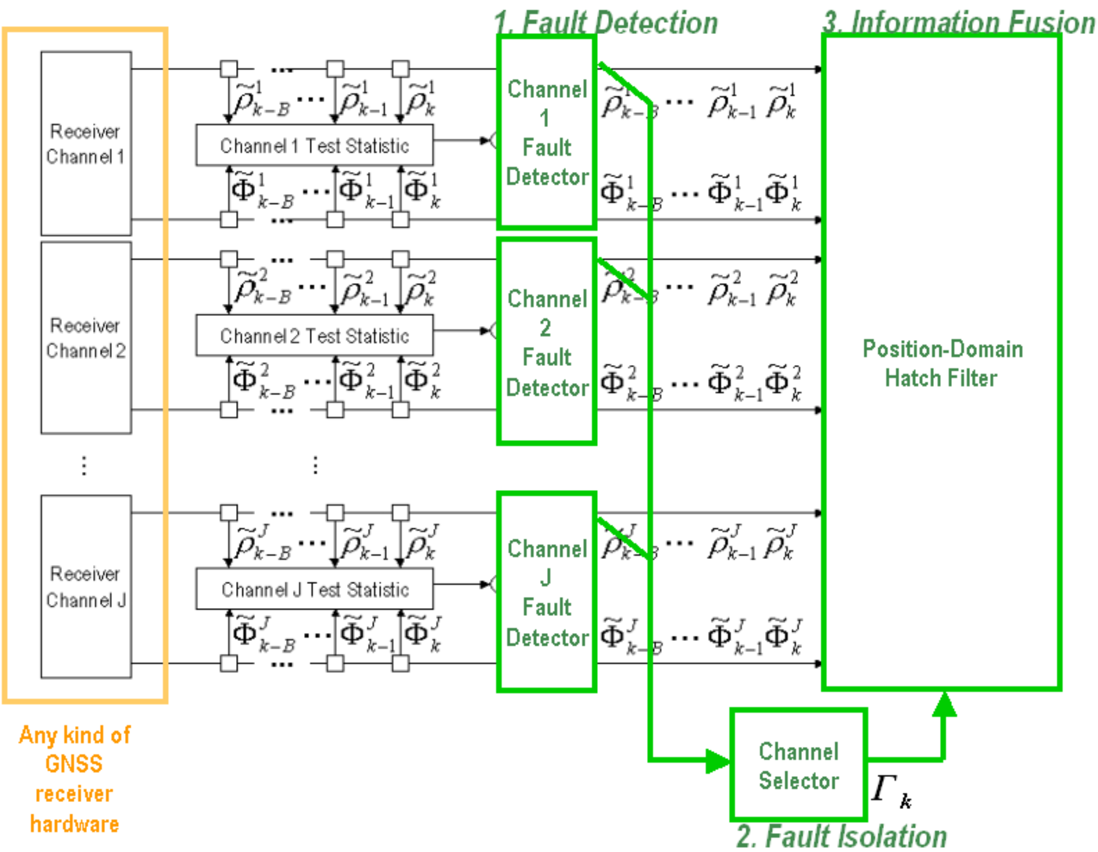

Figure 3. Internal structure of GAFAS (GNSS Algorithm For Accuracy and Safety)

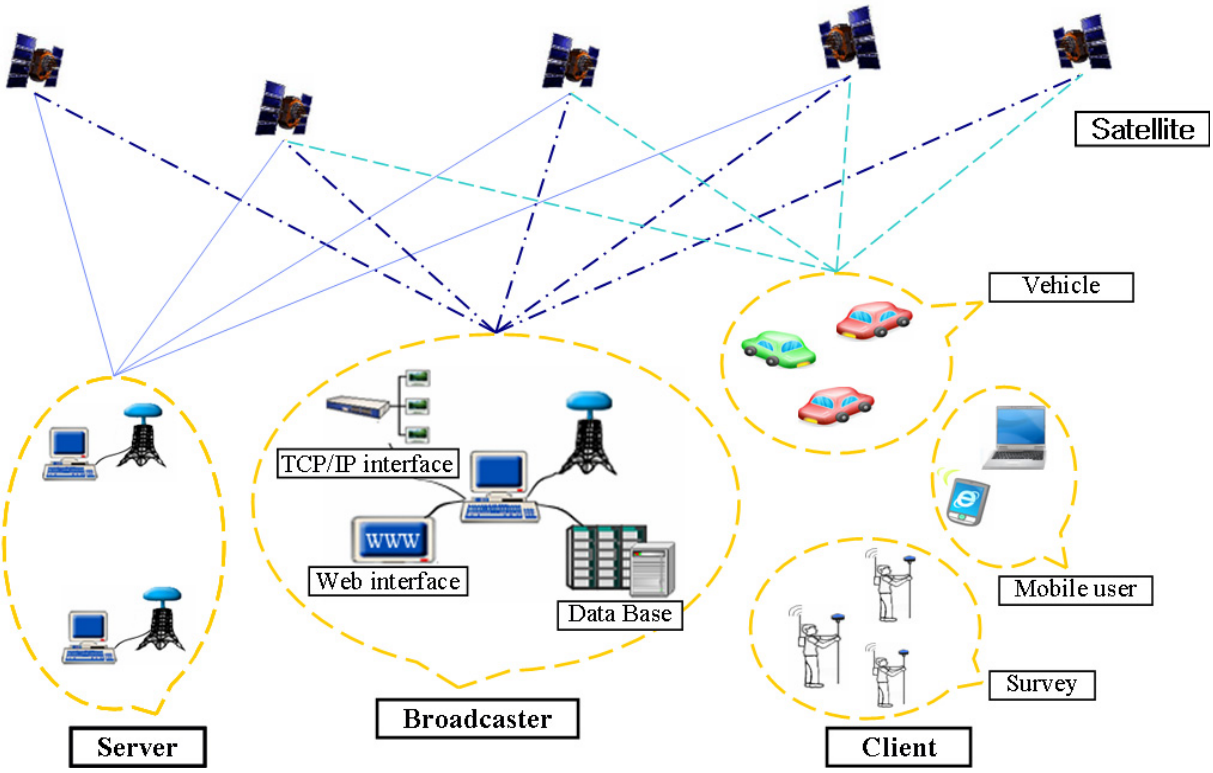

Figure 4. Composition of DGPS network

3. DESIGN OF A GPS RECEIVER NETWORK

Figure 4 shows the configuration of the designed GPS receiver network. The designed receiver network consists of a single broadcaster, several servers, and bulks of clients. The broadcaster consists of the TCP/IP interface, the web interface, and the database interface. The database interface of the broadcaster manages or stores all the data stream such as user information for the identification, correction data, GPS measurement data in RINEX (Receiver Independent EXchange) format, and so on.

The server is paired with a reference receiver that measures GPS data continuously at known location. The raw GPS measurements of the reference receiver are transformed to the RINEX format observation and navigation files or the real-time correction information stream delivered to the broadcaster based on the TCP/IP protocol. The broadcaster stores the database of the RINEX files and broadcasts correction data in real-time to the mobile users.

The client corresponds to any user such as the vehicle, the mobile device (PDA, cellular phone, laptop computer), or the surveying engineer. The client requests correction data to the broadcaster. Upon the reception of the correction data, the GAFAS algorithm in the client combines its own measurements with the correction data to determine its location in real-time.

3.1 Broadcaster

3.1.1 Prototype equipments & program development tools

● Operating system (OS): Fedora core 6.0 (LINUX)

● TCP/IP interface
  Development language: C-language
  IP / Port: 203.253.146.54 / 20000

● Web interface: Apache web server
  Development language: CGI (C++)

● Database: MySQL 5.0

3.1.2 TCP/IP interface

The broadcaster communicates with the registered servers and clients by the TCP/IP protocol. If a connection request from a server or a client is received, the broadcaster discriminates if the requester is a server or a client through the database search.

If the requester is discriminated as the server, the broadcaster sends the connection success message and receives the ephemeris data from the server. The ephemeris data received from the server is stored in the buffer of the broadcaster. Every time the ephemeris data is updated, the server transmits the updated ephemeris data to the broadcaster.

If the requester discriminated as the client, the broadcaster sends the connection success message to the client. At the same time, as the set of ephemeris data is transmitted from the server to the client. The client estimates its initial position based on its own measurements and the received ephemeris data. The initial position estimate is transmitted to the broadcaster. Upon the reception of the initial position estimate of the client, the broadcaster finds the client's nearest server(s) among the connected servers. After that, the more accurate correction data is transferred from the nearest server to the client. Figure 5 shows this process.

3.1.3 Web interface

Figure 6 and Figure 7 show the designed prototypes of the web interface. The web interface is developed by the common gateway interface (CGI). By the web interface, all the servers and clients register to the designed network. After registering by a simple procedure, the client can receive either the RINEX file or the real-time correction data from the nearest server(s) by the broadcaster.

For management, each server should register its information to the broadcaster by the web interface. The registered information includes the details of the reference station and the reference receiver.

The registered clients can search the RINEX files (navigation file, observation file) sorted according to the time and the reference station.

3.1.4 Database

The broadcaster's database stores the profiles of the servers and clients. It also stores the RINEX file information as shown in Table 1. Figure 8 shows how the web interface and the TCP/IP interface are connected to the database.

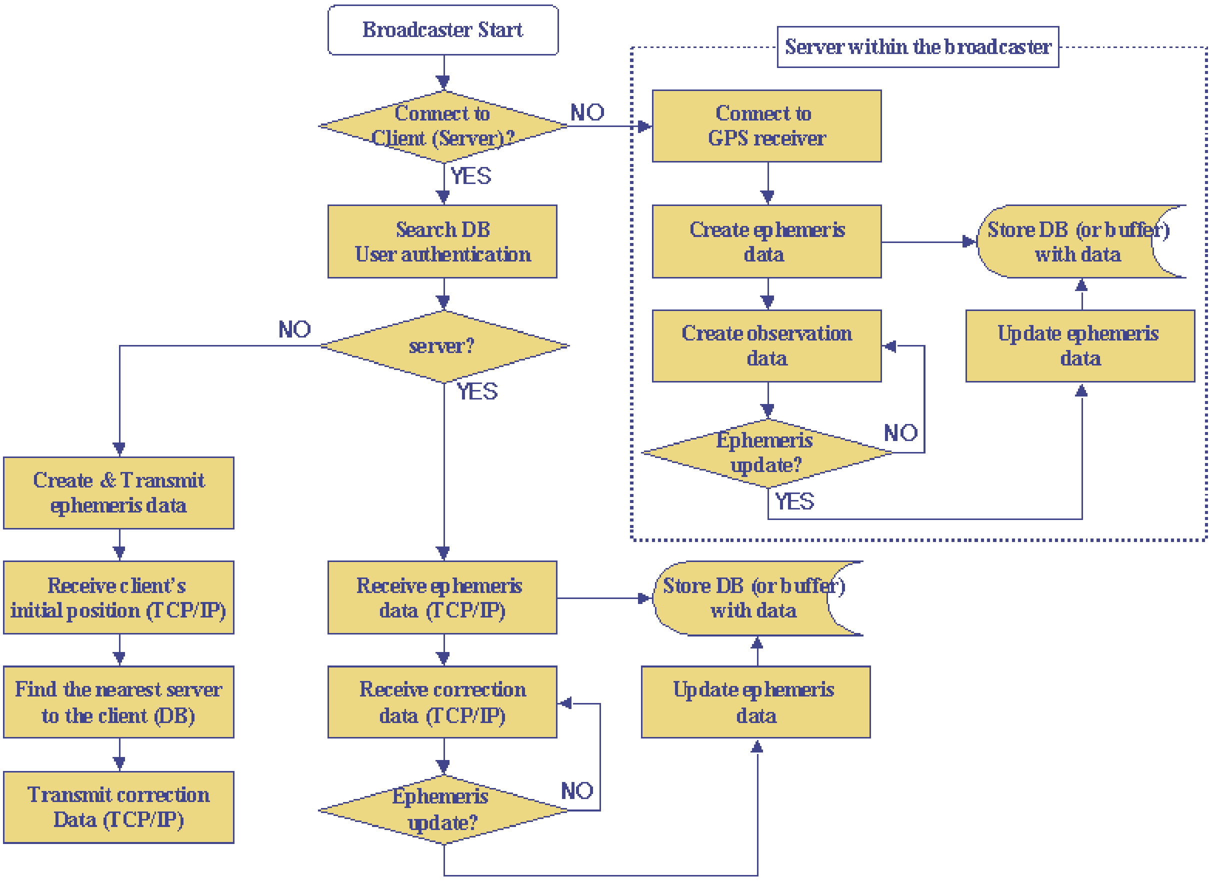

Figure 5. Broadcaster's Flowchart

<table>
<tr><th>Server</th><th>Client</th><th>RINEX files</th></tr>
<tr><td colspan="2">ID, password, address, telephone number, e-mail</td><td rowspan="2">ID
RINEX name
RINEX filename
Reference station name
Observation date</td></tr>
<tr><td>ECEF x, y, z
RINEX name
Reference station name
Antenna type, Receiver type</td><td>User name
Resident registration number
Cellular phone number
and so on</td></tr>
</table>

Table 1. Information stored in database

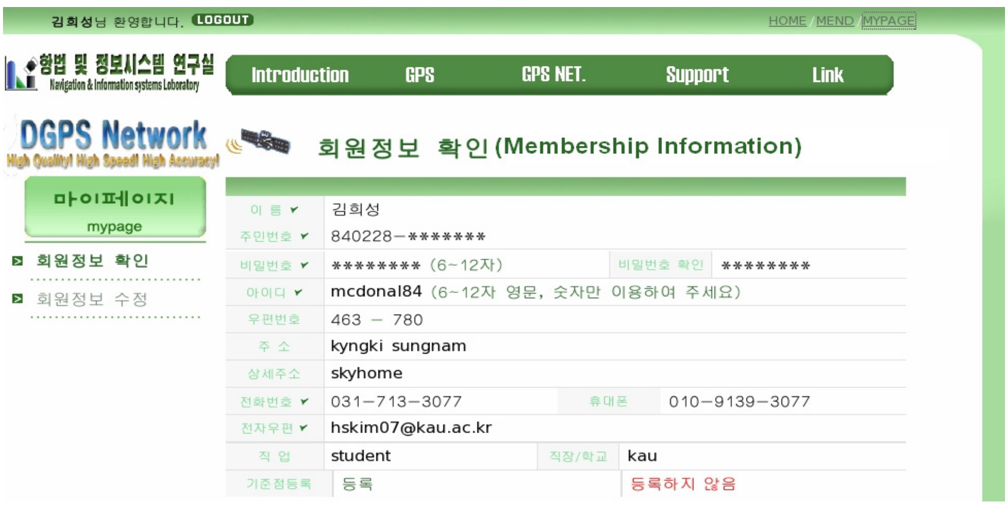

Figure 6. Example of membership information

Figure 7. Snapshot of RINEX data download

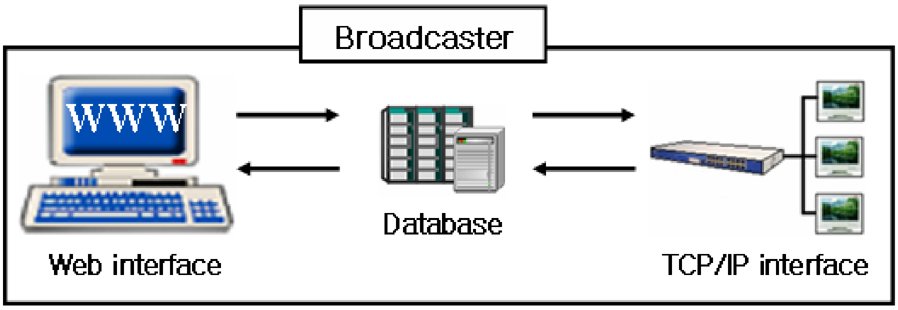

Figure 8. Composition of broadcaster

3.2 Server

3.2.1 Prototype equipments & program development tools

Development language: Visual C++ MFC (windows), C-language (Linux)
GPS receiver: NovAtel DL-4 PLUS (12-channel, dual-frequency)

3.2.2 Functionality

Upon initialization, each server must register itself to the broadcaster by an authentication process. After the completion of the authentication process, the server is completely connected to the broadcaster. The ephemeris data received from the reference GPS receivers of a server is transformed into the RINEX format and transmitted to the broadcaster. The server receives the raw measurements from the reference receiver. After transforming the raw measurements into the various useful forms for correction, the server transmits it to the broadcaster in real-time. Also, as soon as any ephemeris data is updated, it is transmitted from the server to the broadcaster. (Figure 9)

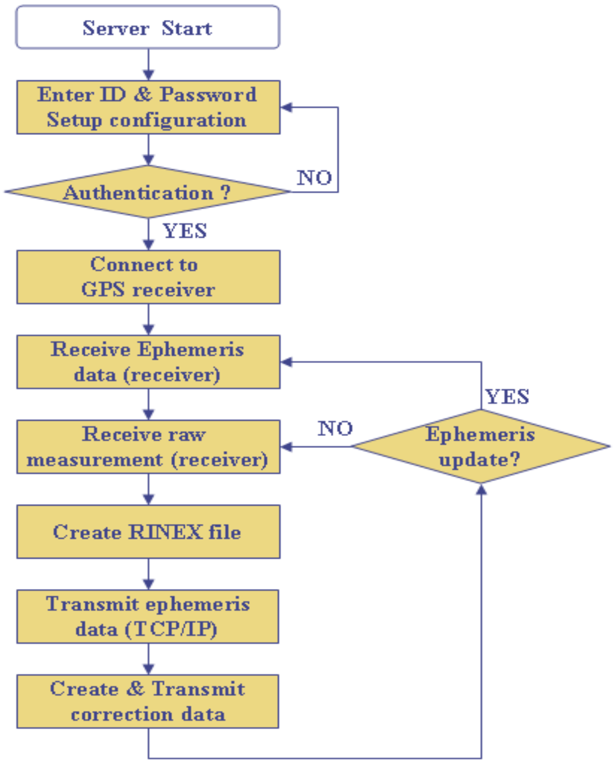

Figure 9. Server's flowchart

3.2.3 Server program operation

Server program is designed either for Windows or Linux operating system (OS) to increase the installation flexibility. Under the Windows environment, the server and broadcaster programes operates independently. Under the Linux environment, however, the single server program can run or the combined server and broadcaster program run. In the latter case, the RINEX files from the combined server are directly stored into database without passing through the combined broadcaster.

Figure 10(a) shows the appearance of the server program under the Windows OS environment. As shown in Figure 10(a), the main window contains various buttons and status windows. By clicking the "Connect" button, the server is connected to the broadcaster. And through the status window that is located centre of the main window, the connection status is verified. The "open" and "send" buttons are for accessing and transmitting the RINEX files to the broadcaster manually.

Clicking the "Settings" button makes the setting window shown in Figure 10(b) to appear. By the setting window, it is possible to enter the IP address and the port number of the broadcaster and the ID and password of the user. To prepare for the unexpected disconnection, it is possible to set the number of reconnection trials and the reconnection intervals.

Clicking the "MakeRinex" button can show the MakeRinex window shown in Figure 10(c) to appear. The role of this window is to make the RINEX data and the correction data from received GPS measurements of the reference receivers.

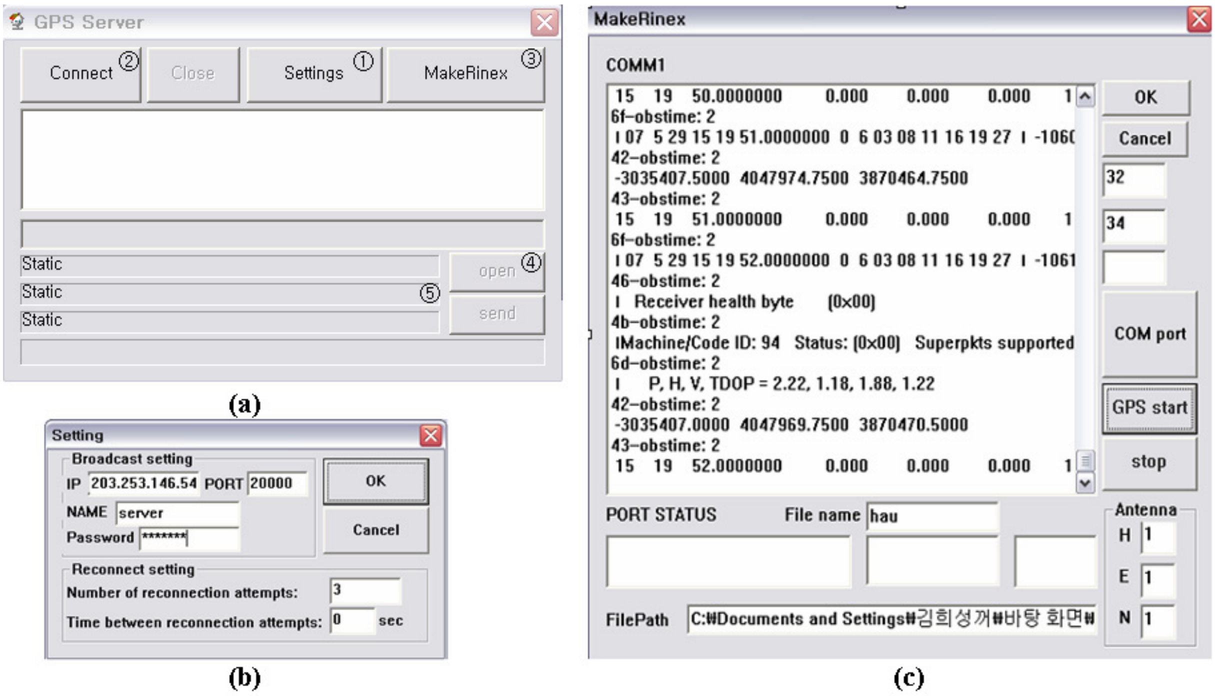

Figure 10. Windows server (a) Main window (b) Setting window (c) MakeRinex window

3.3 Client

3.3.1 Prototype equipments & program development tools

Development language: Visual C++ MFC
GPS receiver: Trimble starter kit (8-channel, single-frequency)

3.3.2 Functionality

When the client program is to be executed, it needs to be registered to the broadcaster. For the registration, the client sends its ID and password information to the broadcaster. Upon the reception of the connection request from the client, the broadcaster determines whether to accept or to reject the request based on its database search result. If the request is accepted, the client receives the connection success message and the ephemeris data from the broadcaster. After a successful registration, client determines its initial position estimate. The initial position estimate is transmitted to the broadcaster. The broadcaster finds the nearest server(s) to the client among connected servers. Finally, a corrected position estimate is produced by the GAFAS algorithm. These procedures are shown in Figure 11.

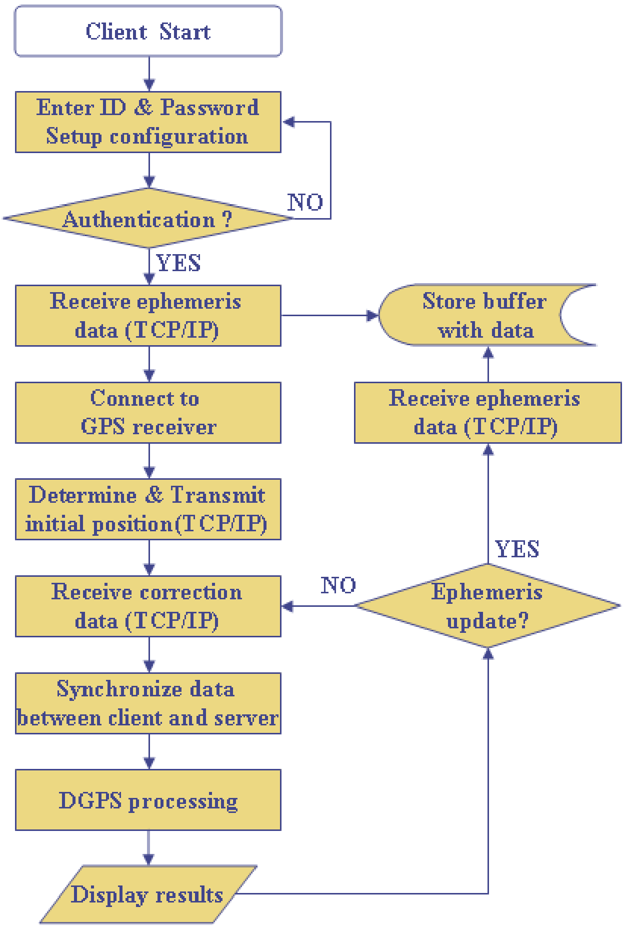

Figure 11. Client's flowchart

3.3.3 Client program operation

Figure 12 shows the main window of the client program. Clicking the "Settings" button makes the setting window appear. By the setting window, the user can set the following items

● Connection with the broadcaster - broadcaster's IP address and port number, user's ID and password

● RINEX file storage – file path

● Connection with the receiver – serial port (port, baud rate, data bit, parity bit, stop bit)

The "Connect" button is purposed to request the connection with the broadcaster after all settings are entered. The "Reconnection" button is to set the number of re-connection trials and the re-connection interval. Figure 12-① shows the list of files that can be downloaded from the broadcaster. Clicking the "Receive file" button initiates the downloading of the selected file. Figure 12-② shows the current settings of the client program. The RINEX files in the current directory are displayed in Figure 12-③.

Clicking the "GPS Start" button makes a new window appear. The configuration of the new window is shown in Figure 13. The user can select choose between the Single Point Positioning (SPP) method and the Differential GPS (DGPS). After that, the GPS data processing is started by clicking the "START" button.

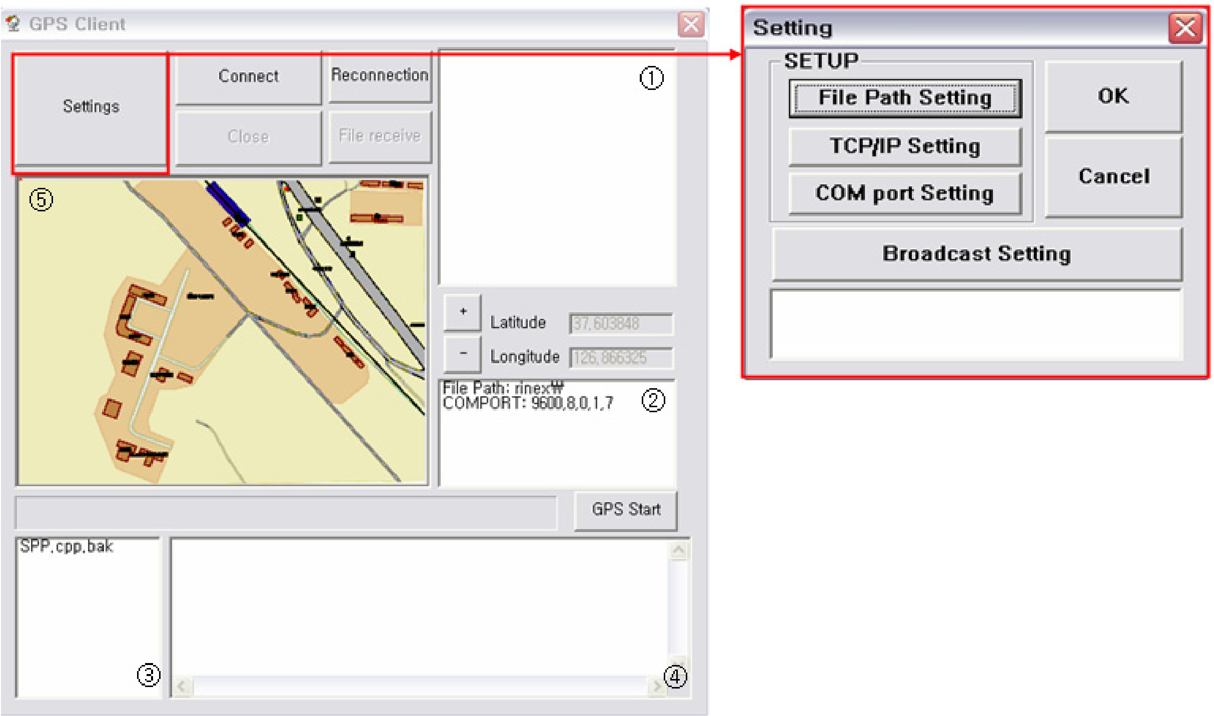

Figure 12. Client's main window and setting window

In the case of the SPP method, the following information is displayed,

● Total number of satellites, latitude, longitude, altitude, status of each satellite, Dilution of Precision (DOP)

In case of DGPS method, the following information is displayed additionally,

● Correction data (in Figure 12-④), connected server name, number of buffer, current processing buffer

Also, the positioning results are displayed on the map as shown in Figure 12-⑤. Figure 14 shows the snapshot of the appearing windows when the DGPS mode is selected.

4. CONCLUSION

This paper dealt with the design and implementation of the GPS/GNSS receiver network entities based on the GAFAS for accurate and reliable RTK applications. The details of the prototype broadcaster, server, and client programs are explained and demonstrated as the initial result.

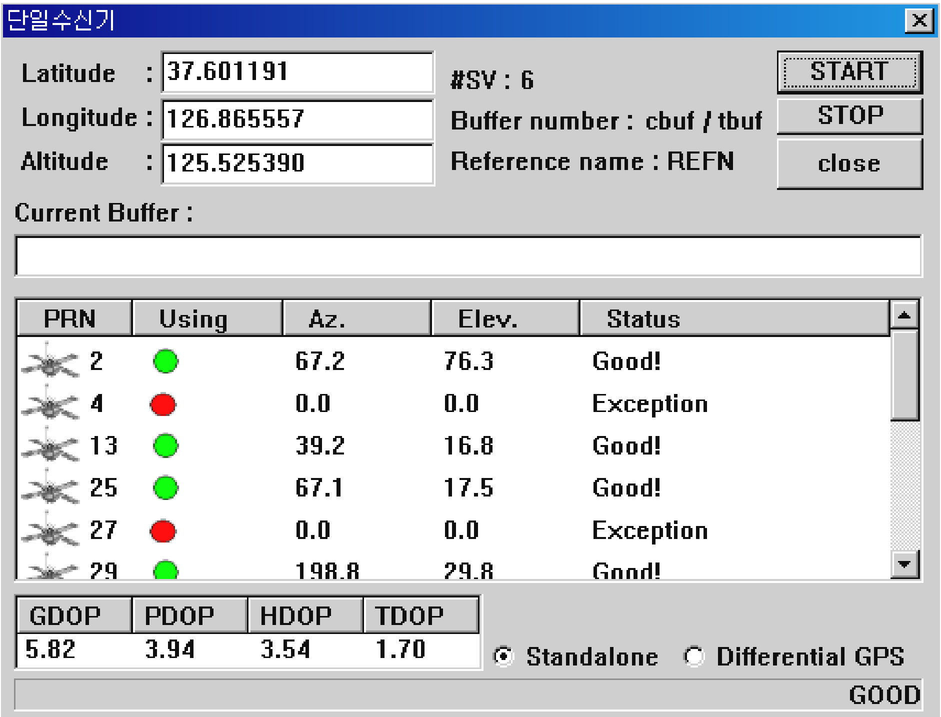

Figure 13. Display the positioning results

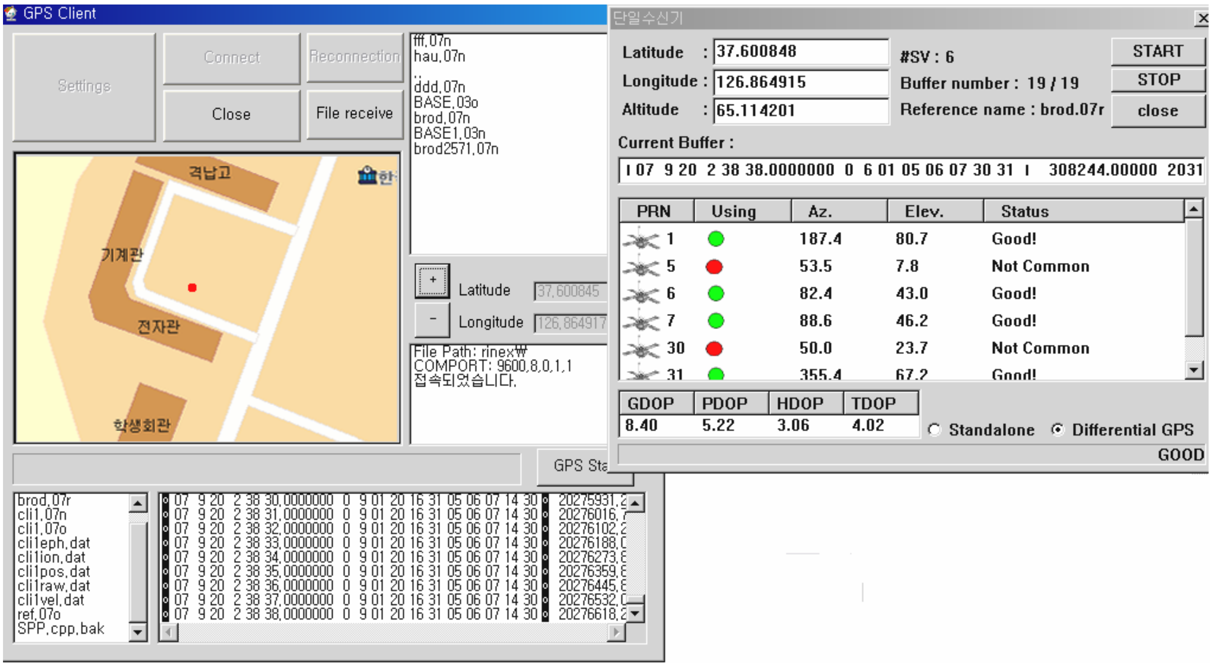

Figure 14. Snapshot of real-time DGPS processing

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