J. Astron. Space Sci. 24(4), 389–396 (2007)

CONCEPTUAL DESIGN OF MONITORING AND CONTROL SUBSYSTEM FOR GNSS GROUND STATION

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(Received September 27, 2007; Accepted October 18, 2007)

ABSTRACT

The Global Navigation Satellite System (GNSS) becomes more important and is applied to various systems. Recently, the Galileo navigation system is being developed in Europe. Also, other countries like China, Japan and India are developing the global/regional navigation satellite system. As various global/regional navigation satellite systems are used, the navigation ground system gets more important for using the navigation system reasonably and efficiently. According to this trend, the technology of GNSS Ground Station (GGS) is developing in many fields. The one of purposes for this study is to develop the high precision receiver for GNSS sensor station and to provide ground infrastructure for better performance services on navigation system. In this study, we consider the configuration of GNSS Ground Station and analyze function of Monitoring and Control subsystem which is a part of GNSS Ground Station. We propose Monitoring and Control subsystem which contains the navigation software for GNSS Ground System to monitor and control equipments in GNSS Ground Station, to spread the applied field of navigation system, and to provide improved navigation information to user.

Keywords: GNSS, ground station, monitoring and control

1. INTRODUCTION

The Global Navigation Satellite System (GNSS) consists of space segment, ground segment, and user segment. The space segment is a satellite system which broadcasts navigation information. The ground segment is a ground facility such as GNSS Sensor Station, GNSS Control Center, Uplink Station, etc. The user segment is the group which uses the navigation information. If the GNSS is used, the navigation information can be acquired easily in global area. As the GNSS is applied in various fields, the ground segment gets more important for using the navigation system reasonably and efficiently. Many countries are developing the global/regional navigation satellite system and making efforts to acquire GNSS technology. For making the GNSS as an accurate and stable system, the role of GNSS Ground Station (GGS), a part of ground segment, is important. The GGS monitors GNSS signal and evaluates navigation quality. According to this trend, the ETRI (Electronics and Telecommunications Research Institute) is developing technologies for the GGS. The one of purposes of this study is to develop the high precision receiver for GNSS sensor station and to provide ground infrastructure for better performance services on navigation system. Thus, the analysis about

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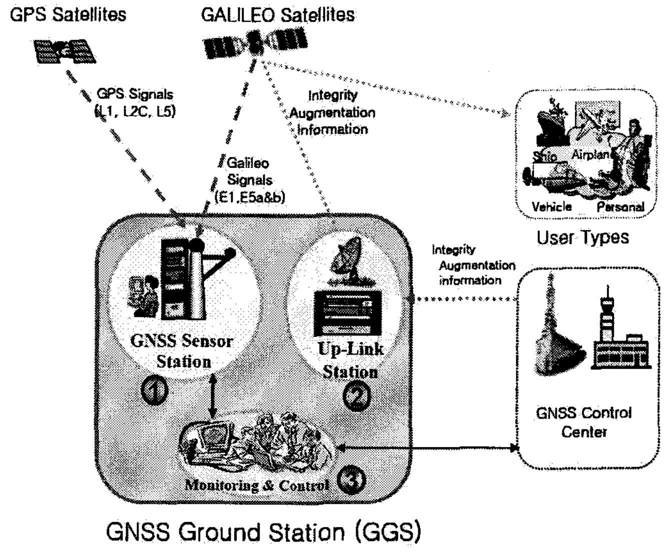

Figure 1. GGS Configuration.

the technology of the GGS is inevitable. This research provides the baseline of the technology of the GSS (Jacobson 2007).

In this study, we consider the configuration of GGS and analyze the functions of MAC (Monitoring And Control) subsystem as a part of GGS. We analyze the GGS system in section 2 and we consider the MAC subsystem in section 3. Section 4 and 5 describe the function and analysis design of the MAC subsystem and the conclusion will be followed.

2. GNSS GROUND STATION CONFIGURATION

The GGS System consists of GNSS sensor station (GSS), Monitoring and Control (MAC), and Uplink station (ULS). ETRI is developing technologies for the ground station as a part of infrastructure for GNSS which includes GPS and Galileo system. The main objective of the GGS development is to develop the core technologies of ground station for GNSS such as high precision receiver for GNSS sensor station, uplink facility, and operation software. The intended service is to provide ground infrastructure for better performance services on GNSS with GNSS mass chipset. The GGS shall be designed to acquire GNSS information and process acquisition data on the ground. The GGS shall provide functionality of sensing and monitoring integrity of signal in space (SIS), gathering navigation data, processing data, transferring it to a proper user, receiving, and transmitting mission data to proper space vehicle. The main purpose of the overall GGS is to develop the key technology development (Gerein, Manz & Clayton 2003).

Figure 1 shows the configuration of GGS which consists of a GSS, an ULS, and a MAC. The GNSS Sensor Station consists of multiple Galileo/GPS receiver units, a reference clock unit, a meteorological unit, and power supply unit. The Uplink Station consists of a ULS control and monitoring unit, a modem baseband unit, RF equipment unit, and antennas. The MAC subsystem consists of

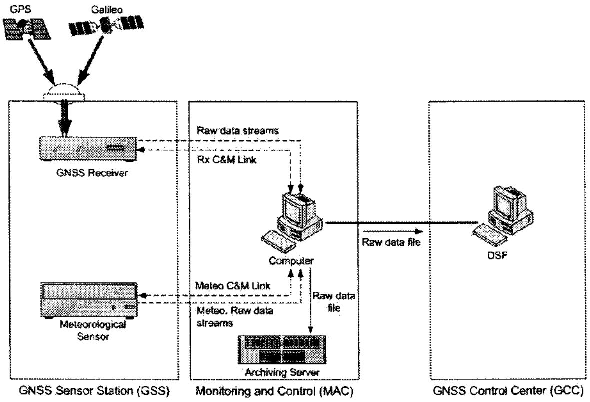

Figure 2. MAC Configuration.

navigation software, software for monitoring and control, and system management software. Especially, the MAC subsystem analyzes and verifies the measurement and navigation data. The GGS provides the interfaces with external system (GCC, GNSS Control Center) to transmit the information of GNSS navigation signal and to receive GNSS message from GCC.

3. MONITORING AND CONTROL SUBSYSTEM DESCRIPTION

3.1 Configuration and Interface

The main objective of the MAC subsystem is to process the raw data stream transmitted from GSS and transfer the corresponding results to the GCC. The hardware of the MAC subsystem consists of a computer and an archiving server. The configuration of the MAC subsystem is shown in Figure 2. The MAC subsystem has the interface with GSS and GCC. GSS provides the observation data and measurement data to MAC. For the precise processing, GSS, also, provides meteorological data. The GCC operates GNSS satellite and monitors the maintenance of GNSS system. The GCC, also, determines the GNSS integrity and signal properties. For this function, GCC needs the GNSS satellite signal which is received by GSS. The MAC receives navigation data, observation data, meteorological data, and monitoring data from GSS. The MAC sends equipment control command to GSS and raw data file to GCC. The MAC provides data which is needed by GCC. The MAC has the archiving server for analysis and monitoring of GGS data. The MAC performs the overall GGS software functions. The MAC has another interface with GSS for C&M which means the control and monitoring of equipment. The MAC controls and monitors GSS equipment.

3.2 Functional Analysis

The objectives of the MAC subsystem are to provide the data for the quality monitoring of signal, determine improved accuracy, monitor and control the equipment of GSS, and then improve the availability to the Galileo Open Service (OS) and the Global Positioning System (GPS) Standard Positioning Service (SPS). In order to meet the objectives, the MAC subsystem collects and processes all data for navigation service provided from GSS, verifies the quality of the data and computes navigation solution. The MAC subsystem also monitors and controls the GSS equipment for GSS

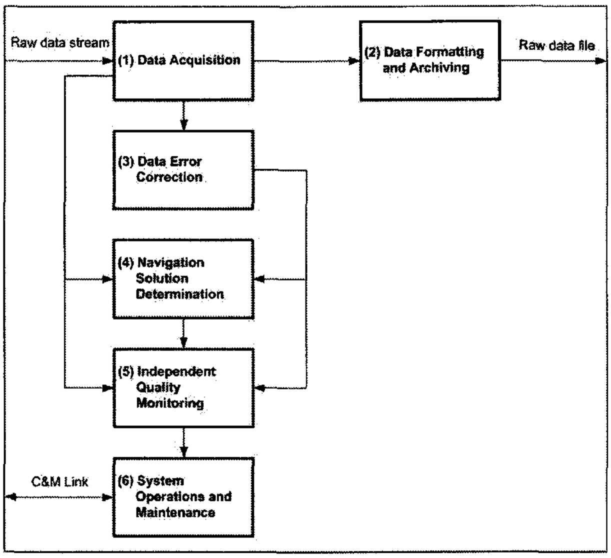

Figure 3. Functional Block Diagram of MAC.

maintenance.

The MAC is a computing system that operates GSS. The MAC is connected to the GSS with the interface of C&M link and raw data stream. The MAC includes six primary functions. These functions are: (1) Data Acquisition, (2) Data Formatting and Archiving, (3) Data Error Correction, (4) Navigation Solution Determination, (5) Independent Quality Monitoring, (6) System Operations and Maintenance.

The MAC functional requirements will be accomplished through a combination of software development and communications. The functional relationships among the MAC functions are shown in Figure 3. Each of the six functions is numbered in Figure 3 and corresponds to the six functions described above.

The MAC subsystem has the functions of data acquisition, data formatting and archiving, data error correction, navigation solution determination, independent quality monitoring, and system operations and maintenance. The data acquisition function is to collect the measurement data from the GSS. The measurement data are pseudorange, carrier phase, navigation message, and etc. The data formatting and archiving function is to convert the data format for transmitting to external user. The data error correction function provides the measurement data with improved quality by correcting the error elements such as ionospheric delay, tropospheric delay, clock error, and etc. The navigation solution determination function is to calculate the navigation solution using corrected measurement data. This function processes the navigation algorithm and generates precise position using the advanced accuracy algorithm. The independent quality monitoring function verifies the quality of measurement data, navigation message and navigation solution which are provided by GSS. The system operation and maintenance function monitors and controls the equipment of GSS. This function manages the overall system operation and supervises system fault. The data communication, command processing, and status display are also handled.

4. MONITORING AND CONTROL SUBSYSTEM FUNCTION

4.1 Data Acquisition

The MAC has the function of collecting observation data and navigation data from all Galileo and GPS satellites that support the navigation service. The MAC also collects meteorological data from meteorological unit. Using these data, the pseudorange error caused by the troposphere can be minimized. These data are used in post-processing for analyzing navigation performance. The observation data and the navigation data is transmitted from GSS. After receiving the data, the MAC performs reasonability checks. The reasonability checks are important because the incorrect data paralyzes the GGS functions. Though data acquisition function is simple function, it is the an important role for performing the GGS mission. The interface can be applied with various formats.

4.2 Data Formatting and Archiving

The MAC has the function of data formatting and archiving for providing it to GCC. The observation data and the navigation data received from GSS are converted to RINEX (Receiver INdependent EXchange) format. The meteorological data collected by meteorological measurement unit, also, is converted to RINEX format. So the RINEX file has three different types such as observation data format, navigation data format, and meteorological data format. RINEX file is the common data file for presenting the navigation information which is received by GNSS receivers. To save storage space, proprietary formats are mostly binary, which means that they are not directly readable. This creates a problem when combining data from different GNSS receiver. To overcome this problem, MAC uses the RINEX format of the standard ASCII format. Although a file in the ASCII format is known to take more storage space than a file in the binary format, it provides more distribution flexibility. GCC also collects the data with RINEX data format for the same reason.

The MAC has the function of analysis. Therefore, the MAC needs additional data file such as binary and ASCII format. These files are used for converting to RINEX file. The MAC makes identical format file for GCC. The file generated by MAC has 15 minutes period to collect data generally. The MAC archives raw data file collected from GSS and temporarily stores a copy of the GSS raw data file after checking for post processing.

4.3 Data Error Correction

GNSS measurements are affected by several types of random errors and biases. These errors may be classified as those originating from the satellites, those originating at the receiver, and those that are due to signal propagations (Kaplan & Hegarty 2006). Figure 4 shows the main errors and biases.

The errors originating at the satellites include ephemeris or orbital errors, and satellites clock errors. The receiver has the receiver clock errors, multi-path error, antenna phase center variation, and measurement noise. For the signal through the atmosphere, the ionospheric delay and tropospheric delay are added. The MAC has the error correction function for correcting these errors. The MAC estimates ionospheric delay error using multi frequency of GPS and Galileo, and tropospheric delay error using meteorological data. Also, the MAC computes satellite clock error correction and the multi-path error correction.

4.4 Navigation Solution Determination

The calculation of position with GNSS can be performed in MAC Subsystem. In GGS, the calculation of position is the method of verifying the GNSS System. Because the GGS is the fixed sites, the confirming of the GGS position makes the GNSS be reliable. The MAC determines the navigation solution using navigation message and measurement data which is corrected by error

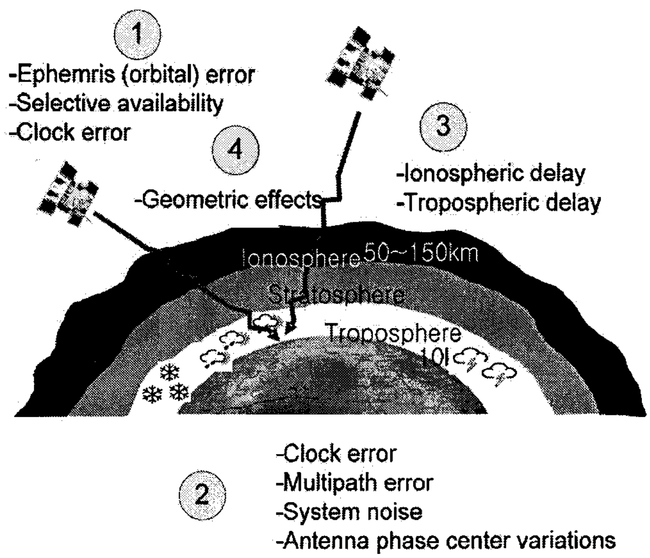

Figure 4. Main GNSS Errors and Biases.

correction method. The MAC performs code carrier smoothing function for deceasing the effect of high frequency error and code information variation induced by receiver noise. And the MAC detects and removes the error of receiver clock bias (Misra & Enge 2001).

The MAC calculates position of antenna point using up to 4 navigation satellite signals transmitted by Galileo and GPS. Using both Galileo and GPS system, the accurate position solution is possible. The MAC fits the difference of time and coordinate system between GPS and Galileo in calculating navigation solution.

4.5 Independent Quality Monitoring

In addition to providing a position, navigation, and timing function, GNSS system should have the ability to provide timely warnings to users when the system is unstable. This capability is the integrity of system and the MAC provides independent quality monitoring function. Although the integrity of GNSS is analyzed in GCC finally, the MAC has the function of quality monitoring independently for controling and monitoring the GSS.

The MAC calculates the dilution of precision of GPS and Galileo and displays the values. The dilution of precision of GPS and Galileo is the index of reliability of the position determination. The MAC verifies the measured pseudorange to compare with the true range based on antenna point and detects the abnormal pseudorange. A cycle slip is defined as a discontinuity or a jump in the GNSS carrier phase measurement and caused by temporary signal loss. Signal loss is caused by obstruction of the GNSS satellites signal due to buildings, bridges, trees, and other object. The MAC shall detect the effect of cycle slip of satellite signal provided by GSS.

The GSS receives the dual frequency channels. Table 1 shows the receive channels of GSS system. Because the true position of receiver is fixed, the MAC can verify the calculated position to compare with the true position of antenna point. The MAC analyzes the GNSS satellite properties and displays the status of received satellite signal and signal anomaly.

Table 1. Frequency Channel Allocation in GPS and Galileo.

Satellite Name	Signal ID	Center Frequency [MHz]	Bandwidth [MHz]
GPS	L1	1575.42	25.0
	L2C	1227.60	22.0
	L5	1176.45	26.0
Galileo	E1	1575.42	25.0
	E5a	1176.45	26.0
	E5b	1207.14	26.0

There are many methods in integrity monitoring such as signal quality monitoring, data quality monitoring, and measurement quality monitoring. The signal quality monitoring is the method which inspects the signal error generated by GNSS satellite anomaly and influenced by the ion storm during signal transmission. Data quality monitoring checks code anomaly, navigation frame error, and satellite almanac information error. Measurement quality monitoring detects the delay due to ion storm, multi-path error, and receiver measurement noise.

4.6 System Operation and Control

The MAC provides the management function of controling and monitoring GSS equipment. The MAC collects the status information from GSS and controls function of GSS subsystem if necessary. As the GSS system is operated continuously, the MAC should monitor data processing status and provide the control and monitoring function continuously in real time.

The MAC displays GSS equipment status, tracking Galileo and GPS satellite status, Galileo and GPS measurement data, and communication network status and provides alarm via visual and audio instrument when the system anomaly occurs. The MAC also provides the analysis tools. The MAC stores the data for playback, performance analysis, performance verification, data analysis, and simulation.

In the equipment control, the MAC shall have hardware remote initialization function for reset of fault situation. The MAC stores event log information function for supporting maintenance and repair function. The MAC provides graphical user interface based on multi-window.

5. ANALYSIS DESIGN

The MAC functions are analyzed in the view of Object Oriented Analysis (OOA) and Object Oriented Design (OOD). For OOA and OOD methodology, the standard Unified Modeling Language (UML) notation is considered. Figure 5 shows the main use case diagram of MAC. Use case diagram describes system requirements in the viewpoint of the user and the external view of the system.

For guaranteeing the performance, MAC has the criterion about processing time, ionospheric correction, and tropospheric correction. The MAC, also, has the limits of alarm time and fault detection time. These performance criterions enhance reliability of MAC subsystem. The proposed MAC system meets the requirement which is needed by GSS. The MAC has not only data transmission function which is the original function of GSS but also the addition functions such as quality monitoring, navigation solution determination, and data error correction. These functions assist GSS to be operated independently and the usage of GSS to expand. Therefore, GSS which interfaces with MAC subsystem can monitor GNSS system independently if the operator wants. If the GSS includes the MAC subsystem, it also can be applied to the wide/local area augment system of GNSS.

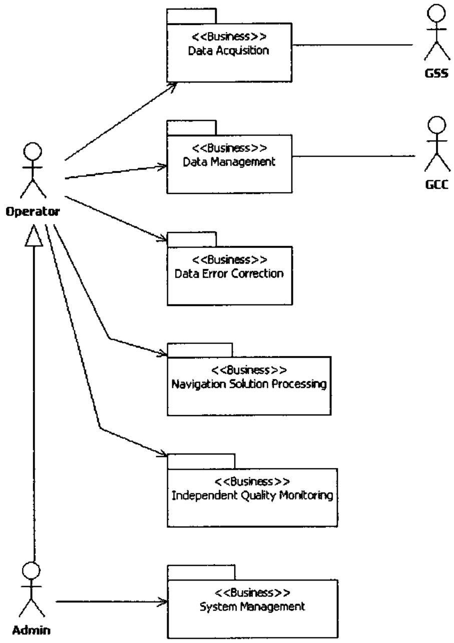

Figure 5. Use Case Diagram of MAC.

6. CONCLUSIONS

As the navigation system is getting more important in commercial and national defense field, the various navigation data processes are required. In this paper, we propose the MAC subsystem in GGS. If the proposed subsystem is used, the application field of GNSS system will be expanded. The improved navigation information can be provided to GNSS users.

ACKNOWLEDGEMENTS: This work was supported by the IT R&D program of MIC/IITA. [2007-S-301-01, Development of Global Navigation Satellite System Ground Station and Search And Rescue Beacon Technologies].

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