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Current Status and Plan for Maritime Precise Positioning and   
Integrity Monitoring Service in the Republic of Korea

# introduction

Maritime autonomous applications refer to the use of advanced computer systems and sensors to control unmanned vessels or boats. These autonomous vessels can be used for a wide range of purposes, including surveying, shipping, logistics, environmental monitoring, security and defence, fishing, and aquaculture. One of the applications that are emerging with the implementation of automation is cargo handling. Cargo handling automation involves the use of robotic systems to load and unload cargo from ships, without the need for human intervention. This can improve efficiency, safety, and reduce costs in the shipping industry. However, to operate safely and effectively, these autonomous vessels and cargo handling systems require precise positioning and navigation. Precise positioning and navigation are essential components of maritime autonomous applications, enabling these vessels to operate safely, efficiently, and effectively in a range of environments and applications. Navigation safety is paramount for autonomous vessels as they need to identify hazards in their environment, and take necessary precautions to avoid them. Additionally, they need to navigate accurately to reach their intended destination and complete their mission.

GNSS (Global Navigation Satellite System)-based positioning and navigation systems are used in maritime autonomous applications to determine the position, velocity, and timing of the vessel. The most commonly used GNSS system is GPS (Global Positioning System), which globally provides positioning and navigation data using a network of satellites orbiting the Earth. However, GPS is not always reliable, and it also does not provide the positioning accuracy required by maritime autonomous applications. To overcome these limitations, researches are being conducted on GNSS-based positioning and navigation systems that use additional sensors, such as LIDAR, radar, and sonar, to improve the accuracy and reliability of the positioning and navigation data. Among these sensors, GPS is the only system that provides absolute positioning data.

Maritime autonomous applications require high-precision positioning accuracy to operate safely and effectively. The required accuracy depends on the specific application, but in general, the accuracy required is typically in the range of centimetre to decimetre-level. For example, in applications such as hydrographic surveying, precise positioning is required to ensure that the vessel follows the intended survey line and collects accurate data. Even small errors in positioning can result in data that is unusable or incorrect. Similarly, in cargo handling automation, precise positioning is critical to ensure that the robotic systems can handle cargo precisely and safely, avoiding potential hazards. In addition to accuracy, positioning reliability and integrity are also essential components of maritime autonomous applications. Reliable positioning is critical to ensure that the vessel can navigate safely, even in challenging environments such as port and restricted waters. Integrity refers to the confidence level that the positioning data is correct and reliable, which is critical in ensuring the safety of the vessel and its surroundings.

To achieve the required accuracy and reliability, GNSS-based augmentation technologies such as RTK (Real Time Kinematic), PPP (Precise Point Positioning), and PPP-RTK are used in maritime autonomous applications. These technologies provide correction information from reference stations, which are used to improve the accuracy and reliability of the positioning data. This paper introduces the POINT (Precise Positioning and INTegrity monitoring) project conducted by the Republic of Korea (ROK) and describes the architecture of the precise positioning and integrity monitoring system proposed by the POINT project. The POINT project carries out from 2020 to 2024, consisting of two phases. The first phase includes the completion of the critical design review for precise positioning services. Thereafter, the validation of development technologies was completed, along with the verification of the positioning performance through the testbed. In the second phase, the critical design for navigation service was completed by 2023. And this year 2024, we are performing POINT system performance verification. This paper shows some of the performance verification results for the POINT system performed this year.

# point system

## Precise positioning technologies

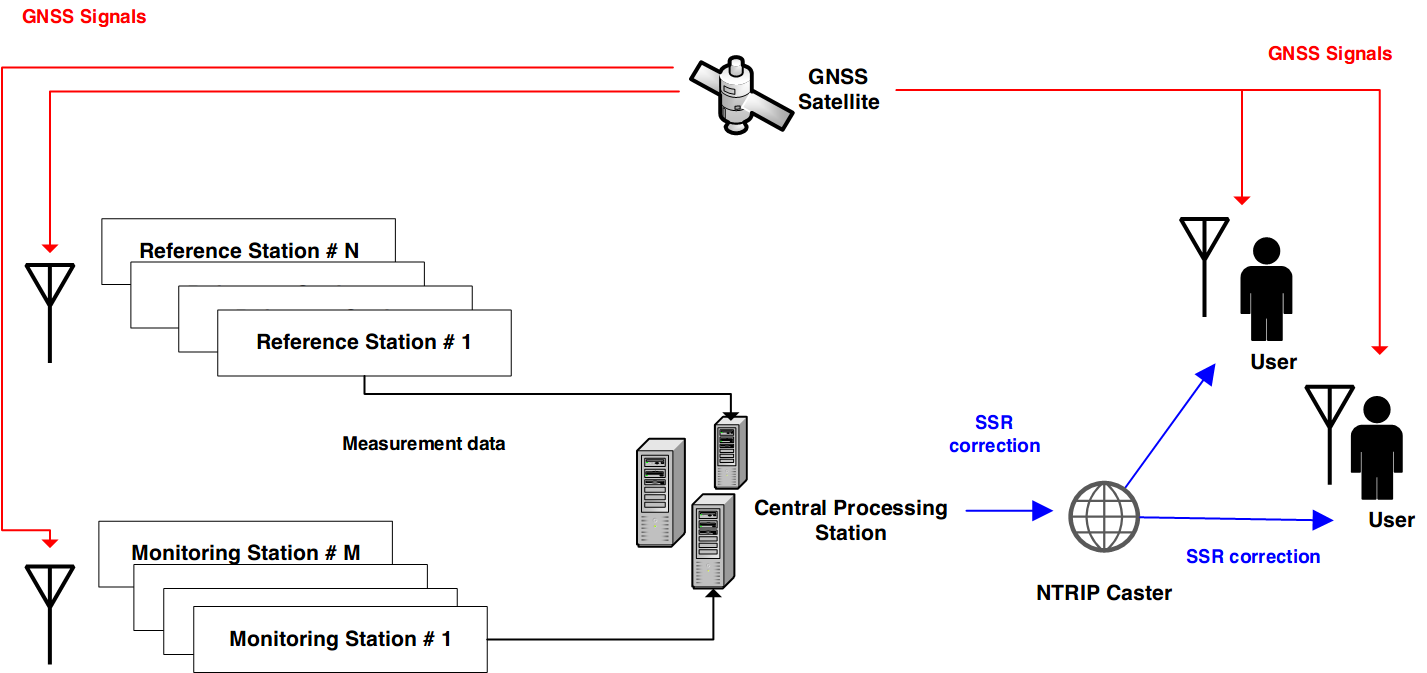
Since the early 2000s, many users in the marine environment have claimed a need for precise positioning at the centimetre-level. In response, the International Maritime Organization (IMO) published resolution A.915(22), which mandates that the horizontal and vertical absolute accuracies be less than 10 cm for automatic docking, cargo handling, construction, and dredging [1]. In the Republic of Korea, the Ministry of Oceans and Fisheries is supporting the development of a new positioning service for maritime users to meet these accuracy requirements. The ground-based centimetre-level maritime precise Positioning, Navigation, and Timing (PNT) augmentation service called POINT will provide centimetre-level positioning using a state-space-represented (SSR) global navigation satellite system (GNSS) augmentation message to users within a maximum of 100 km from the coastline. The correction and integrity information will primarily rely on the Korean National Maritime PNT office's (NMPNT) reference station (RS) and monitoring station infrastructure, which is currently used for Differential GNSS (DGNSS) service

In recent years, the SSR GNSS correction has rapidly developed and becomes widely used in various correction/augmentation systems [2-4]. In contrast to the RTK method, which uses observation-space-represented (OSR) correction [5], SSR correction distinguishes GNSS errors from the measurement domain into state variables, such as satellite orbit, satellite clock, ionosphere delay, and tropospheric delay, according to their characteristics. The traditional PPP technique widely uses SSR corrections of satellite orbit and clock to achieve decimetre-level accuracy. To further improve accuracy and reduce convergence time, PPP can be combined with phase bias to enable ambiguity resolution after combining an ionosphere-free combination, a technique known as PPP-Ambiguity Resolution or PPP-AR [6]. Additionally, the PPP-RTK technique [7], which includes ionosphere and tropospheric corrections as well as phase bias, has been introduced. PPP-RTK can reduce the convergence time of PPP-AR by interpolating spatial corrections in small- or medium-scale networks.

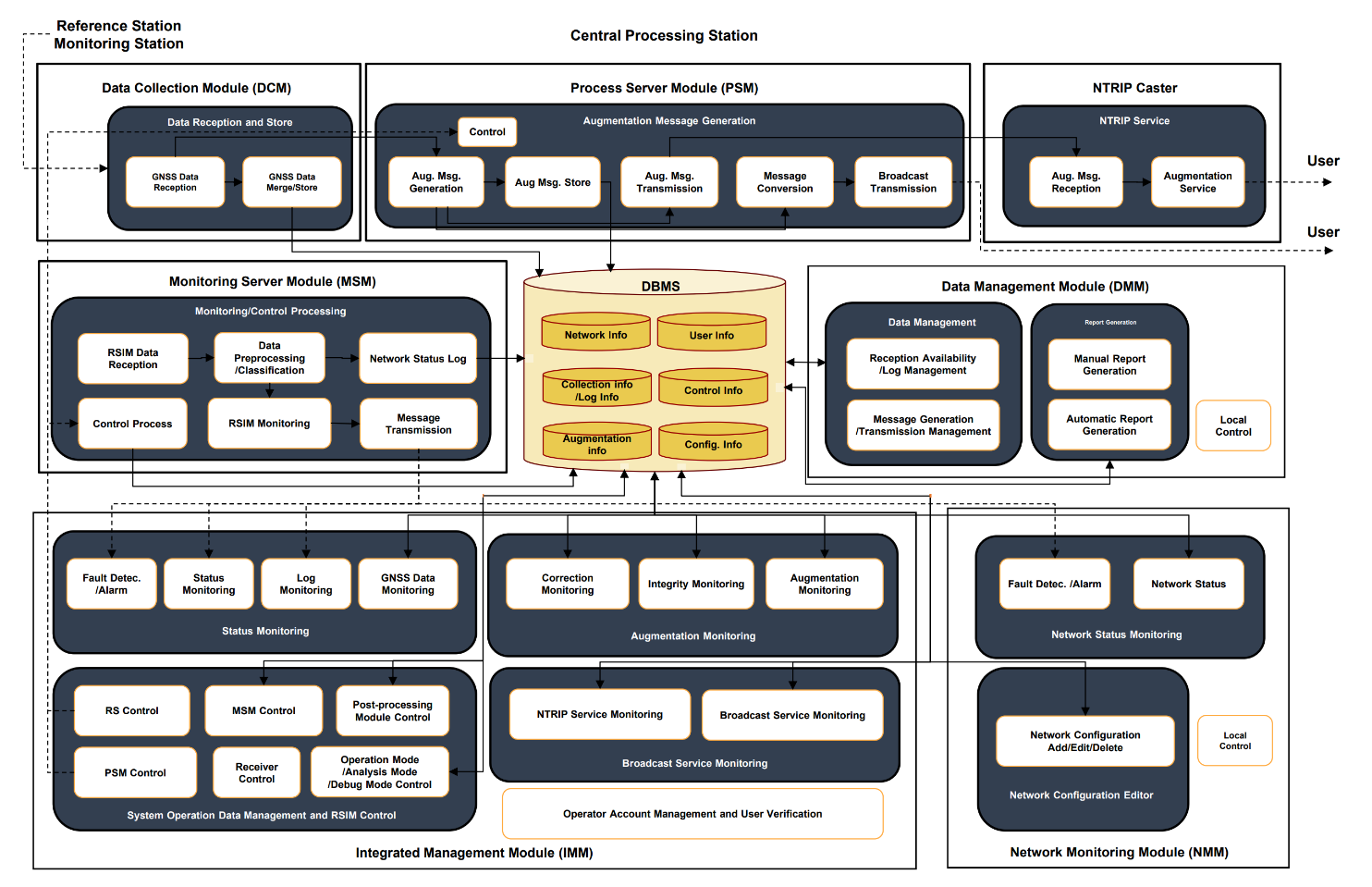
Governments, proprietors, and organizations operate numerous services that use PPP, PPP-AR, and PPP-RTK technologies. The Quasi-Zenith Satellite System with Centimetre-Level Augmentation Service (QZSS CLAS) is an open nationwide PPP-RTK service for Japan that has been operational since November 2018 and provides correction and integrity messages in Compact-SSR format [8]. The High Accuracy Service (HAS) of the European satellite navigation system, Galileo, is scheduled to provide open PPP-AR correction through the Galileo E6-B signal and terrestrial means [9]. Galileo HAS will provide PPP-AR corrections, including satellite orbit, clock, and biases for global users in service level 1 (SL1), and atmospheric correction for European users in service level 2 (SL2). The PPP of the China satellite navigation system, BDS, provides PPP correction through the BDS B2b signal using 3 BDS GEO satellites. The coverage of BDS PPP is the China and its surrounding areas in the scope of 10°N~55°N, 75°E~135°E.

## Architecture of POINT system

The architecture of the POINT system is divided into two segments: the service segment and the user segment [10, 11]. The RS, central processing station (CPS), and integrity monitoring station (IM) are the three main module blocks in the service segment, whereas the user segment includes the receiver platform (RP). Figure 1 shows the overall block diagram of the POINT system. The RS and IM in POINT form a Continuously Operating Reference Stations (CORS) network that receives GNSS signals from GNSS satellites. Consequently, the CPS receives raw data directly from the RS and IM.



1. Overall block diagram of POINT system



1. POINT CPS architecture

The CPS merges all navigation message data and rearranges the code and carrier phase observables. After pre-processing and applying a priori models, the CPS estimates PPP-RTK corrections based on the precise coordinates of the RS. Simultaneously, the PPP-RTK correction data are tested and verified in the IM measurement data. The SSR correction message is generated from the correction data through the designed POINT message format, and the binary message is transferred by the Networked Transport of RTCM via Internet Protocol (NTRIP) caster. Once the RP accesses the SSR correction message with the NTRIP client, in addition to the GNSS signals, the user can correct the GNSS raw measurement with SSR correction data parsed from the correction message.

The RS block comprises three parts: GNSS signal reception, environment, and operations/control. The GNSS receiver and antenna are part of the GNSS signal reception section, and if necessary, the receiver clock can be replaced with an atomic clock. Similarly, the IM block includes GNSS signal reception, environment, and operations/control parts. In most cases, IM stations are operated and controlled by the CPS, but they can also operate independently in a local operation mode.

The CPS manages most system functions, including data management, correction generation, integrity monitoring, and correction message transmission. Figure 2 illustrates the CPS modules and their interactions. The process server module (PSM) generates augmentation data from the data collection module (DCM) and converts it into POINT message format. A database management system (DBMS) and data management module (DMM) are implemented to store raw data, correction data, status, and logs of each module fed continuously.

# results of performace verfication

The following table shows the performance verification results for the 16 days conducted in July 2024. Performance verification was conducted by the monitoring stations. During the period, the average of horizontal position accuracy was 4.67 cm, and the average of vertical position accuracy was 9.89 cm. In addition, during that period, all integrity of the horizontal position was satisfied. In addition, it was applied to vehicles such as ships and drones to confirm performance.

1. Positioning accuracy and availability

|  |  |  |  |
| --- | --- | --- | --- |
|  | Horizontal Accuracy  (rms, cm) | Vertial Accuracy  (rms, cm) | Availability  (%) |
| Day 01 | 3.76 | 7.22 | 100% |
| Day 02 | 4.14 | 8.72 | 100% |
| Day 03 | 4.65 | 9.18 | 100% |
| Day 04 | 4.16 | 8.62 | 100% |
| Day 05 | 4.95 | 11.17 | 100% |
| Day 06 | 6.13 | 11.23 | 100% |
| Day 07 | 5.06 | 9.79 | 100% |
| Day 08 | 4.82 | 9.66 | 100% |
| Day 09 | 3.99 | 9.44 | 100% |
| Day 10 | 4.51 | 11.69 | 100% |
| Day 11 | 4.06 | 9.04 | 100% |
| Day 12 | 4.15 | 9.05 | 100% |
| Day 13 | 5.48 | 10.88 | 100% |
| Day 14 | 4.26 | 9.93 | 100% |
| Day 15 | 5.82 | 10.62 | 100% |
| Day 16 | 4.78 | 11.97 | 100% |

# conclusions

In 2015, a research was conducted in the ROK to plan precise positioning services and to confirm the demand and need for advanced maritime augmentation services. Based on this research, the ROK initiated the POINT project in April 2020. The POINT project aims to develop an infrastructure that provides users with precise positioning and integrity monitoring information in the maritime sector, with the goal of achieving an improved location accuracy of 5cm (rms, horizontal) and 10 cm (rms, vertical). And in 2024, the last year of the project, the POINT system performance verification is being conducted targeting the Korean maritime pilot service.

Currently, the ROK is promoting the development of the Maritime Autonomous Surface Ship (MASS) R&D project, and the results of the POINT project will be associated with it. Moreover, after completing the verification of POINT service performance, a pilot service covering all coasts, including the ports, is expected to be released in December 2024.

We would also like to make efforts to expand technologies related to maritime precise positioning and navigation by periodically sharing the status of POINT and other satellite-based radionavigation service projects with IALA member countries through the IALA ENG Committee.

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