Multisource-based Cloud-Native Hybrid Positioning Platform for Emergency Location Service

Dongwook Choi[1,*], Chanyeong Park[1] and Chaewon Lee[1]

[1] Korea Telecom, Geumto-ro 32, Sujeong-gu, Seongnam-si, Gyeonggi-do, Republic of Korea

Abstract

In this paper, we present work in progress of the multisource-based cloud-native hybrid positioning platform to improve the quality of emergency location service by Korea Telecom. Since 2019, the Korea Communications Commission has publicly announced the test results of the MNOs emergency location service's positioning quality, which are classified by three positioning methods, GPS, Wi-Fi, and base station, in terms of accuracy and time. The main guideline for positioning accuracy is as follows: 50 metres horizontal location accuracy and 30 seconds total positioning time limit. Recently, followed by the Federal Communications Commission guideline of vertical positioning requirements, 3 metres z-axis with 90% probability is challenged by many stakeholders. To achieve these quality requirements for emergency location service, Korea Telecom is setting a new challenging accuracy target and working to provide enhanced emergency location services from the perspective of an end-to-end location platform using a cloud-native hybrid positioning platform.

Keywords

emergency location service, smartphone, hybrid positioning, cloud-native, platform

1. Introduction

To obtain faster and more accurate location information for emergency rescue, Assisted-Global Navigation Satellite System (A-GNSS) positioning from the caller's mobile phone [1] and Wireless-Fidelity (Wi-Fi) access point signals are widely used indoors and outdoors [2, 3]. In the US, the Federal Communications Commission (FCC) has proposed enhanced regulations for 911 emergency location-based services, requiring a horizontal positioning accuracy of 50 metres with a total positioning time of 30 seconds and a vertical positioning accuracy of 3 metres indoors [4, 5]. As a technical alternative to meet the enhanced vertical positioning accuracy requirements, a method for estimating vertical location information using the barometric pressure sensor of mobile phones has been studied [6, 7]. Korea Telecom (KT) is developing a hybrid positioning platform based on multisource of smartphone to provide emergency location-based services. KT's application modernisation with a cloud-native hybrid positioning platform can be a catalyst for the rapid commercialisation of more diverse positioning methods for emergency location services.

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* Corresponding author.
matthew.choi@kt.com (D. Choi); chanyeong.park@kt.com (C. Park); lee.chaewon@kt.com (C. Lee)
0000-0003-2020-9883 (D. Choi); 0009-0003-2312-1868 (C. Park); 0009-0009-1455-8498 (C. Lee)

2. Emergency Location-based Service in South Korea

Unlike the US and EU approaches to emergency location service, in South Korea, the request for emergency location service is initiated by the public safety answering point. The location information of the requestor's device is obtained through Mobile Network Operator (MNO) in what is commonly referred to as the Network Initiated (NI) method in the Open Mobile Alliance (OMA) Secure User Plane Location (SUPL) and 3rd Generation Partnership Project (3GPP) LTE Positioning Protocol (LPP) standard [8, 9]. In addition, the Korea Communications Commission (KCC) has been conducting its own annual evaluation of the quality of emergency location service since 2019 and disclosing the results to the media.

2.1. Emergency Location Positioning Procedures

Emergency location services are involved in many system entities. To make a brief description of currently provided emergency location service in South Korea, figure 1 shows conceptual architecture of emergency location service configuration [10]. The architecture is consisted of four entities: Public Safety Answering Point (PSAP), Location Manager, Positioning System and device. PSAP is operated by government, for instance, police department or fire department. PSAP performs answering emergency request calls and dispatches. To make efficient dispatches, location information of caller is required. PSAP is interfaced with MNO to acquire the caller's immediate location information. Location manager and positioning system as shown in figure 1 are operated by MNO to make user's immediate location information.

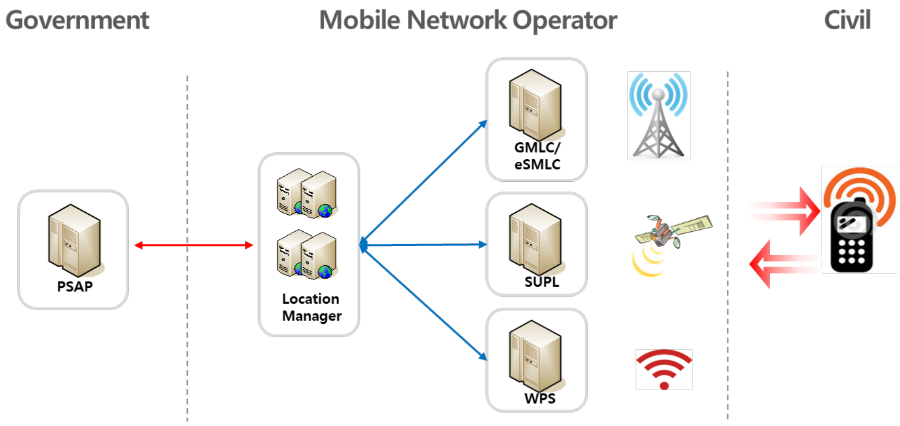

Figure 1: End to end emergency location service entities.

In brief demonstration, emergency location service is delivered as follows:

1. PSAP requests user's location information to MNO
2. MNO receives PSAP request
3. Location manager triggers positioning data
4. Positioning system wakes User Equipment (UE)
5. UE performs raw data measurement for positioning
6. Measured raw data is delivered to positioning system
7. Positioning system estimates user's location
8. Location manager response user's location to PSAP

2.2. Positioning Quality Assessment for Emergency Location Service

In order to support rapid and accurate rescue activities of first responders, the KCC has been measuring the quality of emergency rescue location information since 2019 and disclosing the results to encourage mobile network operators to invest in emergency rescue precision positioning technology and improve its quality.
The evaluation items are as follows:

1. Location standard satisfaction rate: The percentage of the provided location information that meets the distance error standard (within 50m) and location response time standard (within 30 seconds)
2. Location accuracy: The distance error between the actual location of the rescue point and the location information provided by measuring it
3. Location response time: The time it takes to receive location information from the time the rescue organisation requests it from the carrier.

In 2024, the KCC publicly announced that, as a result of this quality measurement, the distance (within 50 metres) and response time (within 30 seconds) standards of the three mobile operators were met at 98.2% to 97.7% for GPS and 93.6% to 96.8% for Wi-Fi, which showed an increase from the previous year, but overall at a good level. In addition, the location accuracy, which refers to the distance error between the actual location of the measurement point and the positioned location, was significantly improved from 21.6m to 11.3m for GPS, 34.2m to 20.1m for Wi-Fi, and 107m to 52.3m for base station [11].

3. Barometric Assist Data based Hybrid Positioning Technique

Multisource-based hybrid positioning technologies are being researched and developed to improve the accuracy of emergency rescue location information. For rapid emergency rescue operations, the FCC guides regulations on the use of vertical location information [5]. Technologies using Wi-Fi access points, beacons, etc. have been examined to provide vertical location information [12, 13]. Recently, various experiments have been made to combine and utilise barometric sensor data from smartphones [6, 7, 13, 14]. KT proposes a hybrid positioning technique using barometric correction data to reduce the error range of smartphone barometric sensors and ease of use.

3.1. Hexagonal Cluster Virtual Automatic Weather Station Assisted Data

Height above sea level is a measure of the vertical distance between the earth's surface and mean sea level. This mean sea level, on which height above sea level is based, is set as a long-term average value for the entire planet. However, different regions have different heights above sea level, and accurate elevation measurements need to account for these regional differences in real-world applications [15, 16]. It is important to refer to national or international datum points for accurate elevation measurements.

To provide vertical positioning information based on smartphone barometric pressure sensors in the Emergency Location Service efficiently, KT suggests utilising hexagonal cluster based the virtual Automatic Weather Station (AWS) data that is estimated from the collected data sets in real time through automatic weather stations as shown in figure 2. The virtual AWS data is estimated by microsphere interpolation technique [17] to provide a particular hexagonal cluster's barometer, temperature etc. immediately.

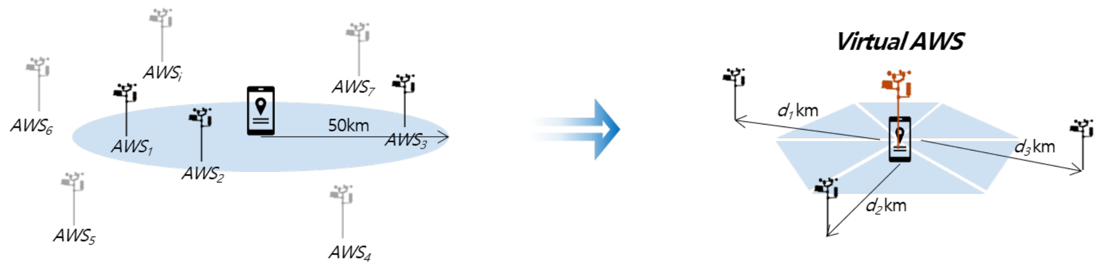

Figure 2: Generation of hexagonal cluster's virtual AWS from real time AWS data collection.

To conduct hexagonal cluster's virtual AWS data, determine AWS data sets to interpolate in the order of near distance,

$$d_i = \|x - x_i\| \quad (1)$$

where x is centre coordinate of hexagonal cluster, x_i is ith AWS's coordinates d_i is ith Euclidean distance.

To set a weight factor of d_i,

$$w_i = \frac{1}{d_i^p} \quad (2)$$

where w_i is ith AWS's weight factor that is proportional to the reciprocal of d_i. p is typically works as a power factor, but due to the characteristics of AWS data (temperature, altitude, barometer, etc.) it is not distance dependent, so set to 1.

To obtain interpolated data of the virtual AWS,

$$\widetilde{w_i} = \frac{w_i}{\sum_{j=1}^{N} w_j}, \quad (3)$$

$$f(x) = \sum_{i=0}^{N} \widetilde{w_i} f(x_i) \quad (4)$$

where N is number of data sets of AWS, to perform a fast acquisition, $\widetilde{w_i}$ is normalised w_i and $f(x_i)$ is the value of the function at each data point x_i.

3.2. Barometric sensor-based Vertical Positioning

When Emergency Location Services provide elevation information to first responders, it is common to use Mean Sea Level (MSL) for elevation information. However, using MSL contains errors because the height of sea level varies from region to region [15]. Also, since rescue operations are conducted at ground level, it is more efficient from the user's perspective to provide elevation information based on ground level.

To estimate vertical positioning data, smartphone provides its raw measurements data, *latitude, longitude* and P_{org}. *latitude* and *longitude* are smartphone's horizontal positioning result of GNSS technique, P_{org} is its barometric sensor data, respectively. Since smartphone's barometric sensor contains errors, it is possible to calibrate those errors, P_{cal} by utilising crowd-sourcing technique that is not discussed more details in this paper [6]. Sea level elevation of the smartphone h_b is calculated using Geographical Information System (*GIS*) that uses Digital Elevation Model (DEM) based on horizontal coordinate of smartphone's GNSS positioning result,

$$h_b = GIS[GNSS_{lat}, GNSS_{lon}] \quad (5)$$

where $GNSS_{lat}$ and $GNSS_{lon}$ are smartphone's GNSS positioning result *latitude* and *longitude*, respectively. To estimate virtual AWS data set, pressure P_b and temperature T_b are calculated by microsphere interpolation in equation (4).

Figure 3 shows overall parameters of estimate ground height of smartphone based on GNSS and barometric sensor utilising virtual AWS. The correlation between air pressure and elevation has been the subject of extensive research and is defined as follows:

$$P = P_b \cdot \left[1 + \frac{L_b}{T_b} \cdot (h - h_b)\right]^{\frac{-g_0 \cdot M}{R \cdot L_b}} \tag{6}$$

where L_b is standard temperature lapse rate, h is height about sea level, R is universal gas constant, g_0 is gravitational acceleration constant and M is molar mass of Earth's air. To calculate elevation, equation (6) is inversed as follows:

$$h = h_b + \frac{T_b}{L_b} \cdot \left[\left(\frac{P}{P_b}\right)^{\frac{-g_0 \cdot M}{R \cdot L_b}} - 1\right] \tag{7}$$

where P is smartphone's barometric sensor data where we calibration factor P_{cal} is applied so that $P_{org}=P+P_{cal}$. Finally, smartphone's height from the ground, h_g is estimated by $h_g=h-h_b$.

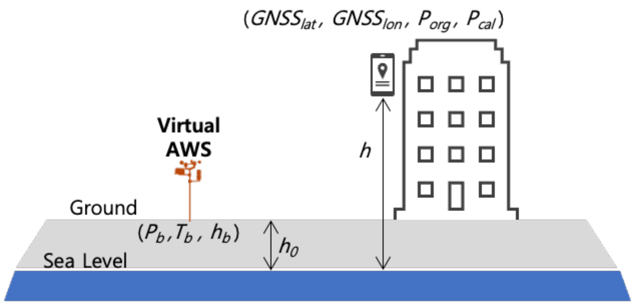

Figure 3: Smartphone's ground height estimation using GNSS, barometric sensor and virtual AWS.

3.3. Field Test Result

To verify the vertical positioning performance of the proposed smartphone barometric sensor, we chose test points in Seocho-gu, Seoul and Gwangmyeong-si, Gyeonggi-do, and conducted tests. A total of 107 points were selected in Seocho-gu and 95 points were selected in Gwangmyeong-si. For the performance analysis, we tested four Samsung Galaxy S series devices that has barometric sensors. To compare the vertical positioning performance, the comparison groups were selected and tested in the same building, such as outdoor, indoor lower floors, indoor middle floors, and indoor upper floors. In the performance analysis, 30 vertical positioning tests per smartphone were conducted at each test point to eliminate statistical outliers.

Figure 4 shows the test results to verify the performance of the smartphone barometric sensor-based hybrid positioning platform. The test results were grouped into ground level, low level, mid level and high level to identify the specificity of each test site and test altitude, and the performance was analysed for the ground floor, first to second floor, third to sixth floor, and upper seventh floor.

Table 1
Test Environment

	Seocho-gu	Gwangmyeong-si
Buildings	27	26
Test Points	107	95
- Ground Level	27	26
- Low Level	41	36
- Mid Level	25	27
- High Level	14	6

The left side of figure 4 indicates the performance of the vertical positioning CEP 80 tested in Seocho-gu, showing an accuracy of about 2.4 metres on the ground floor, 2.7 metres on the lower floors, 2.1 metres on the middle floors, and 1.9 metres on the upper floors. The right side of figure 3 represents the performance of the CEP 80 in Gwangmyeong-si, with an accuracy of approximately 2.4 metres on the ground floor, 2.1 metres on the lower floors, 2.4 metres on the middle floors, and 1.1 metres on the upper floors.

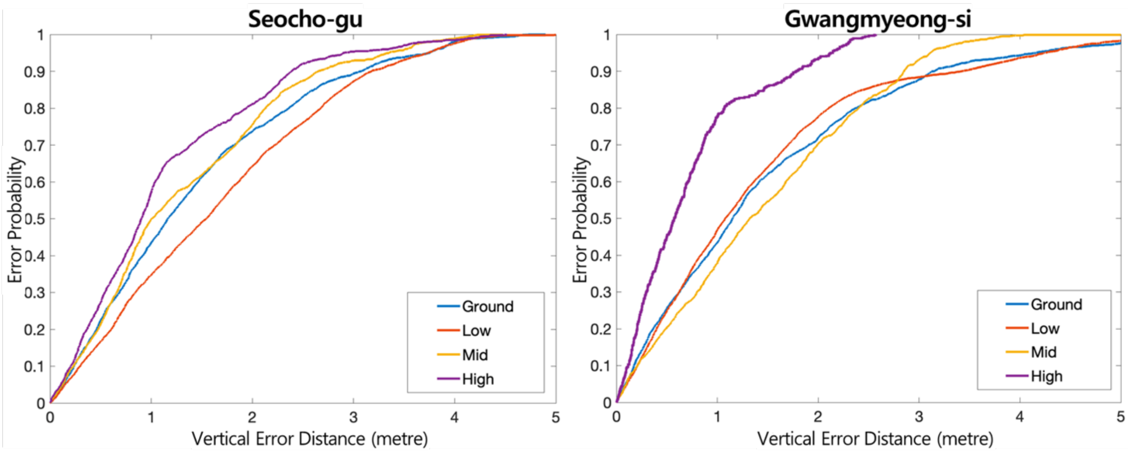

Figure 4: Test result (left) Seocho-gu, (right) Gwangmyeong-si.

4. Cloud-Native Hybrid Positioning Platform

In addition to the conventional positioning techniques such as GNSS, Wi-Fi, and base station positioning in smartphone, alternative positioning resources such as Bluetooth Low Energy (BLE) and barometric sensors are continuously researched and developed [18, 19]. The commercialisation of multisource-based hybrid positioning techniques, which combine more than one specific positioning resources, is rapidly enhancing the quality of emergency location service. KT is researching and developing various positioning techniques to commercialise and accelerate multi-signal and multisensor-based hybrid positioning platform.

4.1. Cloud-Native Application Modernisation

Cloud-based application modernisation enhances a number of advantages over conventional siloed systems [20, 21]. The key advantages in cloud-native hybrid positioning platform include:

1. Scalability: In a cloud environment, you have the flexibility to adjust resources based on the demand of your applications. You can add more servers when you need them, or reduce resources when you don't, which is cost-effective.

2. Flexibility: Cloud-based systems can integrate a variety of services and tools, making it easy to add new features or expand existing systems. This gives you the ability to respond quickly to business needs.
3. Automation and DevOps Support: Cloud platforms support continuous integration/continuous deployment (CI/CD) pipelines, automated testing, and deployment capabilities to speed up development and deployment.
4. Ease of Implementing New Technologies: The cloud provides an environment that makes it easy to adopt the latest technologies such as artificial intelligence (AI), machine learning (ML), and big data analytics.

These advantages help emergency location service respond quickly to technical changes, provide an improved quality of service in positioning, and increase operational efficiency in commercialisation. In the second half of 2023, KT started the development of application modernisation of the location-based service platform include positioning engines, that has been researched and commercialised in silo from 2010 to 2022 over a decade, with the aim of providing better location information. In particular, the transition to a cloud-native hybrid positioning platform using multisensor-based information is expected to enhance the speed of quality improvement that is conducive to practical rescue activities in a commercial environment through CI/CD of precision location technology for emergency rescue, which is being continuously researched and developed.

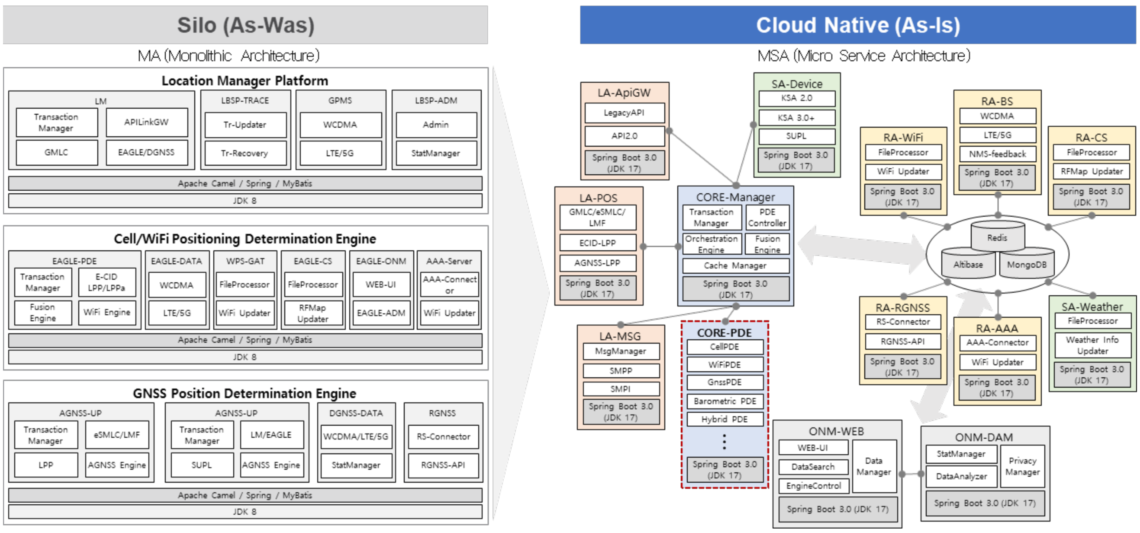

Figure 5: Silo to cloud-native hybrid positioning platform architecture.

Figure 5 describes architecture of the Silo platform, and the Cloud-native Hybrid Positioning Platform developed by KT. The left side of Figure 5 is the Monolithic Architecture (MA), which consists of the Location Manager, base stations and Wi-Fi positioning, GNSS positioning. In order to commercialise products with recently researched and developed to achieve faster and more accurate location information, independent engine or platform must be newly built and directly interfaced with existing platforms in ongoing operation environments. This commercialisation is time-consuming and costly, making it difficult to respond to rapid technological changes. The right side of Figure 5 describes Micro Service Architecture (MSA), which includes all existing siloed functions of one platform, and has the advantage of ensuring CI/CD that can immediately commercialise and manage various positioning technologies by adding or modifying only software modules, especially the CORE-PDE part. In example, barometric assist data-based hybrid positioning technique introduced in Section 3 is also applied as a software module called Barometric PDE, which is configured to operate as a hybrid with the existing positioning function.

5. Conclusion

In this paper, we present a multisource-based cloud-native hybrid positioning platform work in progress that KT is developing for emergency location service. The performance of the cloud-native hybrid positioning platform using the smartphone's barometric sensor-based positioning software architecture, and the platform-based barometric correction information can satisfy the quality requirements for emergency location service proposed by the KCC. As various positioning technologies are developing at a rapid pace, the application modernisation of KT's cloud-native hybrid positioning platform can be one of the ways to accelerate the commercialisation of positioning technologies and quality improvement for emergency location service.

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