# Applying a Deep Learning Enhanced Public Warning System to Deal with COVID-19

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***Abstract*—In Korea, public warning systems are being actively used to provide COVID-19 information to people to avoid additional infections. The explosion of COVID-19 warning messages has caused redundant and unnecessary transmission of warning messages. This study propose an enhanced public warning system. First, a generation model based on deep learning is proposed for automatically generating the coordinates of the broadcast area. Second, the public warning system is modified to provide additional warning information to the users. Finally, a customization scheme for warning information is presented; therefore, the number of redundant and unnecessary warning messages decreases. The proposed generation model is evaluated by measuring the overshooting area and it is compared with the ground truth image. The output of the polygon generator and the circle generator show an image that is similar to the ground truth. The proposed public warning system was implemented, and a test scenario was conducted for the validation. The results demonstrate the feasibility of the proposed public warning system.**

***Index Terms*—Alert area, broadcast area, COVID-19, deep learning, emergency message, public warning system.**

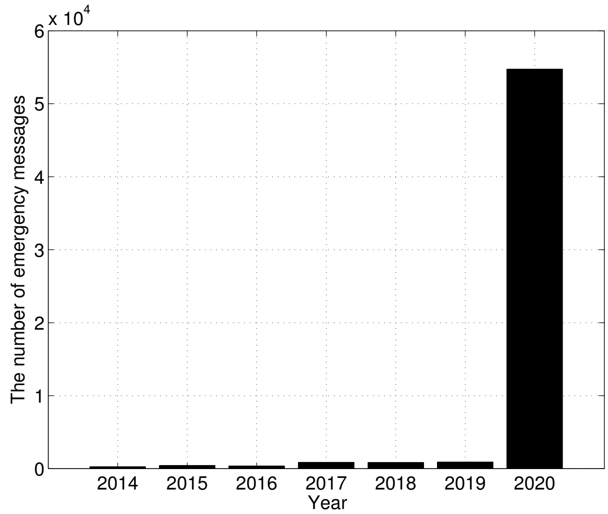


Fig. 1. The number of emegency messages per year in Korea.

## I. INTRODUCTION

SINCE the emergence of COVID-19 in 2019, there have been many changes in our lifestyle. To prevent the spread of COVID-19, personal contact has been minimized, and non-contact communications has increased. For example, instead of face-to-face meetings, online meetings with video conferencing programs, such as Zoom, and Microsoft Teams, are being used. During face-to-face meetings, people should wear masks to prevent infection from COVID-19. In addition to non-face-to-face contact and wearing masks, the Korean government is actively using the public warning system (PWS) to quickly deliver information that is related to COVID-19. Fig. 1 shows the number of PWS warning messages per year [1]. From 2014 to 2019, the number of warning messages gradually increased from 282 to 911. In 2020, the number of emergency messages increased to 54,734 due to COVID-19.

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The PWS transmits text messages through mobile communication networks such as 3G, LTE, and 5G to inform smart device users about information for disasters such as COVID-19, typhoons, earthquakes, tsunamis [2]. The operational sequence of the PWS is as follows. First, the government generates a text message for warning notifications and they determine the broadcast area for the warning message transmission. Mobile communication networks transmit the warning text message to all the base stations in the broadcast area. A base station retransmits the received message to all the smart devices. When a smart device receives the warning messages, it provides a warning message along with a sound and vibration.

During the initial stage of the spread of COVID-19, the text of the warning messages was a very effective way to deal with COVID-19. However, as COVID-19 continued, excessive warning messages that were delivered by the PWS caused several problems. First, overshooting occurs when the broadcast area is wider than the alert area [3]. Fig. 2 shows an example of overshooting. As shown in the figure, some smart device users received redundant or unnecessary messages because of overshooting. Second, the PWS uses longitude and latitude to represent the broadcast area as polygon- or circle-based coordinates. The exact coordinate of the broadcast area requires a delay. However, coordinate generation should be automatically generated for rapid notification. Third, because the length of the emergency text message is limited, the summarized information about the disaster is delivered. Therefore, it is



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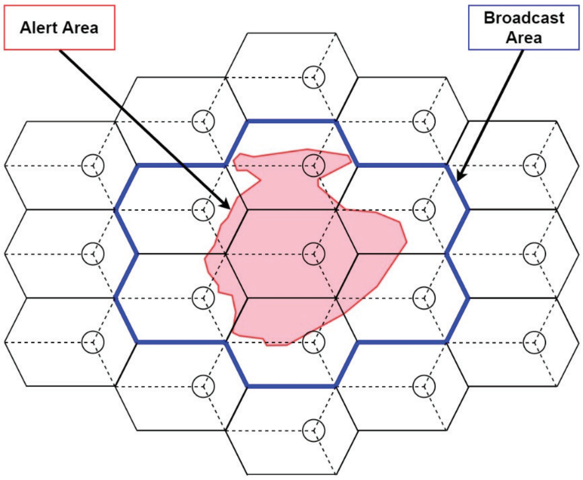


Fig. 2. Overshooting.

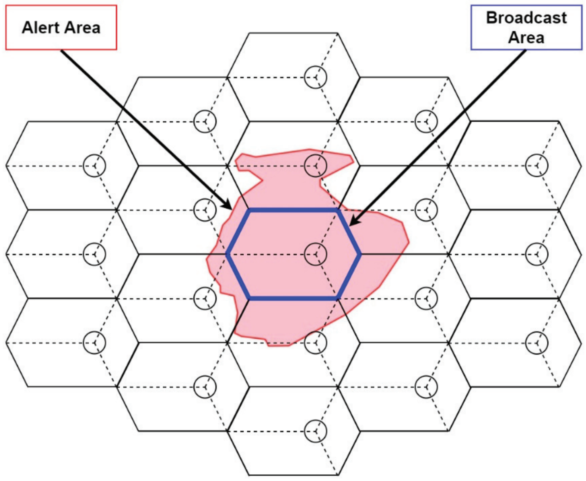


Fig. 3. Undershooting.

difficult to provide customized information to individual smart device users.

Several studies have been conducted on emergency communication systems [15]–[19]. Some studies exploit commercial mobile networks, such as long term evolution (LTE) and 5G [15], [17], [18]. Relay-based emergency communication systems have been proposed to rapidly construct communication systems [15], [19]. The main objective of the previous studies is to reconstruct emergency communications. However, this study focuses on enhancing the PWS.

The investigation aims to increase the efficiency of emergency message transmission and improve the quality of service (QoS) that is experienced by the users. First, this study proposes a coordinate generation model by using deep learning to automatically generate the coordinate of the broadcast area with a minimized overshooting area in order to decrease the transmission delay and the number of unnecessary message transmissions. The proposed two-generation models generate polygon- and circle-based broadcast areas. Second, the PWS is modified to provide additional warning messages to the users. Finally, an algorithm is proposed that customizes the warning messages for users and it removes duplicated warning messages that are received by smart device users.

The remainder of this paper is organized as follows. Section II presents the background and related work. Section III describes the proposed emergency communication system. Section IV provides a discussion about how the proposed scheme was evaluated. Finally, Section V concludes the paper.

## II. Background and Related Work

The PWS that is standardized by a third-generation partnership program (3GPP) refers to a communication system that broadcasts meaningful information to mobile communication subscribers in one direction [2], [4]. In Japan, the earthquake and tsunami warning system (ETWS) has been used to provide evacuation information to reduce the damage from earthquakes or tsunamis [5]. The ETWS broadcasts two types of messages: Primary notifications for time-sensitive information and secondary notifications for additional information about earthquakes and tsunamis. The primary notification was delivered within 4 s. A commercial mobile alerting system (CMAS) has been proposed for warning message transmission in the USA [6]. The CMAS supports three types of messages: A presidential alert, an imminent threat alert, and a child abduction emergency alert. In 2013, the federal communications commission (FCC) renamed the CMAS to wireless emergency alerts (WEA) [7].

The WEA broadcasts a warning message by using geo-fencing. Geo-fencing refers to the technology that is used to specify the virtual area or boundary [12], [13]. In geo-fencing-based services, smart device users receive messages when they enter the broadcast area, which is a virtually defined geographical location. Overshooting and undershooting can occur due to the coverage of the broadcast and alert areas. As shown in Fig. 2, overshooting means that the broadcast area is broader than the alert area. If the alert area is wider than the broadcast area, undershooting occurs, as illustrated in Fig. 3. WEA exploits four different types of alert area information: A commercial mobile alert system (CMAS) geocode, a common alert protocol (CAP) geocode, a polygon, and a circle [3]. The CMAS and CAP goecodes use a 5-bit or 6-bit code that represents a region [14]. However, in the CMAS and CAP geocodes, the overshooting area increases because all the regions, including a part of the alert area, are included in the broadcast area for warning message transmission. To decrease the overshooting area, a polygon- or circle-based broadcast area coordinate is used. The polygon-based broadcast area coordinate information consists of a number of points (pairs of longitude and latitude coordinates). The first point is the same as the last point. The circle-based broadcast area coordinate include the center point (pair of longitude and latitude) and radius.

The PWS uses a cell broadcast system (CBS) to transmit the warning messages [8]. CBS technology broadcasts warning messages without acknowledgement by using geo-fencing [3]. Fig. 4 demonstrates the delivery process of the warning messages in the PWS. The cell broadcast entity (CBE) generates a warning message and transmits the emergency broadcast request, which include the warning message to cell broadcast center (CBC). The CBC identifies the mobility management entities (MMEs) that are based on the geo-fencing information and it transmits write-replace warning requests to the corresponding MMEs. For the acknowledgement, the write-replace warning confirms the message and emergency broadcast response message. These are transmitted from the MME to the CBC and from the CBC to the CBE, respectively. Then, the MME forwards the write-replace warning request message to all the eNodeBs, which includes at least a partial warning area. The eNodeB broadcasts a warning message to all the user equipments (UE) in its own cell. When a device receives a warning message, it informs the user about the type and content of the warning message. After the eNodeB broadcasts a warning message to the UE, it sends a write-replace warning response to the MME. If MME sets the write-replace warning indication option, the MME sends a write-replace warning indication to the CBC. The MME uses the received write-replace warning response to check whether a warning message transmission succeeds. Then, the MME records the transmission history of the warning message for the operation and management system.

Fig. 5 shows the format of the warning message. The warning message consists of nine fields [9]–[11]. The message identifier is used for the message priority and duplication. The default field value ranges from 4,370 to 4,379. If an additional language is used, a decimal value from 4,383 to 4,392 is used. As described in Fig. 5, the serial number field consists of three fields: The geographical scope (GS), message coding, and update number. The two bits are GS bits and they define the transmission range of the warning message: An immediate cell width, a normal PLMN width, a normal tracking area width, and a normal cell width. The message code with 10 bits represents an alert and pop-up option for the warning messages. Two bits are used for emergency user alerts and popups, and the values of the two options are presented in Table I. In the message code, the eight bits are unused. The 4-bit update number refers to the version of the warning message. The initial value of the update number is zero, and the value increases by one whenever the warning message is updated or newly generated. The message identifier field and update number field were used to identify the duplication of a warning message. The repetition-period field is the transmission interval of the warning message. The no-of-broadcasts-requested field indicates the number of repeated transmissions. The data coding scheme field refers to a message-encoding scheme such as UCS2 in Korea. The warning area coordinates field includes a set of coordinates that consist of a latitude and longitude to present the alert area information that is based on a polygon or circle. The format of the polygon- or circle-based alert area information is shown in Fig. 5. The warning message content field contains the content of the warning messages, which includes infectious diseases and disasters, and the maximum content size is up to 315 bytes.

TABLE I
THE FIELD VALUES FOR THE MESSAGE CODE IN THE SERIAL-NUMBER FIELD.

| Field | Code | Instruction |
|---|---|---|
| Emegency user alert | 0 | No instruction for emergency user alert |
| | 1 | Activate emergency user alert |
| Popup | 0 | No instruction for popup |
| | 1 | Activate popup |

Several studies have been conducted on ememengecy communication systems. In [15], an LTE-based emergency communication system was proposed for a power system. To achieve rapid deployment, reliability, and stability, which is similar to ad hoc networks, LTE micro-base stations constitute their own networks by themselves. In [16] and [17], the emergency communication systems for public protection and disaster relief were proposed. In [16], the architecture design of an emergency communication system that is based on a software-defined radio (SDR) was proposed. The system was implemented and validated for various emergency scenarios. In [17], an emergency communication system exploits 5G technology and satellites in order to respond to large-scale dissters such as earthquakes and fires. Three types of architectures were proposed and a testbed was implemented for validation. In [18], the architectures were proposed for a software-defined network layer, UAV cloudlet layer, and a radio access network layer to improve the performance of the public safety LTE (PS-LTE). In [19], a relay-based communication system was proposed to rapidly deploy an emergency communication system. The previous studies in the literature have focused on developing temporal and rapid emergency communication systems. However, this study is focused on the PWS.

## III. ENHANCED PUBLIC WARNING SYSTEM

This section describes the enhanced PWS. First, this section discusses the generative adversarial network (GAN) that can generate polygon- or circle-based coordinates for broadcast areas that deliver warning messages. Second, this section proposes a warning message delivery scheme to provide additional information to smart device users. Finally, this section discusses a scheme for providing customized warning information. A smart device can identify duplicate warning messages and it displays only the usable information that is based on the user's location.

### A. Coordination Generation Model based on the GAN

This subsection discusses the coordinate generation model that is based on GAN. As shown in Fig. 4, after receiving an emergency broadcast request, the CBC determines the broadcast area for the warning message delivery. To minimize the gap between the alert and broadcast areas, the PWS uses the polygon- or circle-based coordinates of the broadcast area. For an automatic coordinate generation model that is based on a polygon or circle, this study cropped a number of images for an alert area from a geographic information system (GIS) [20]. This investigation collected 4,765 images of administrative

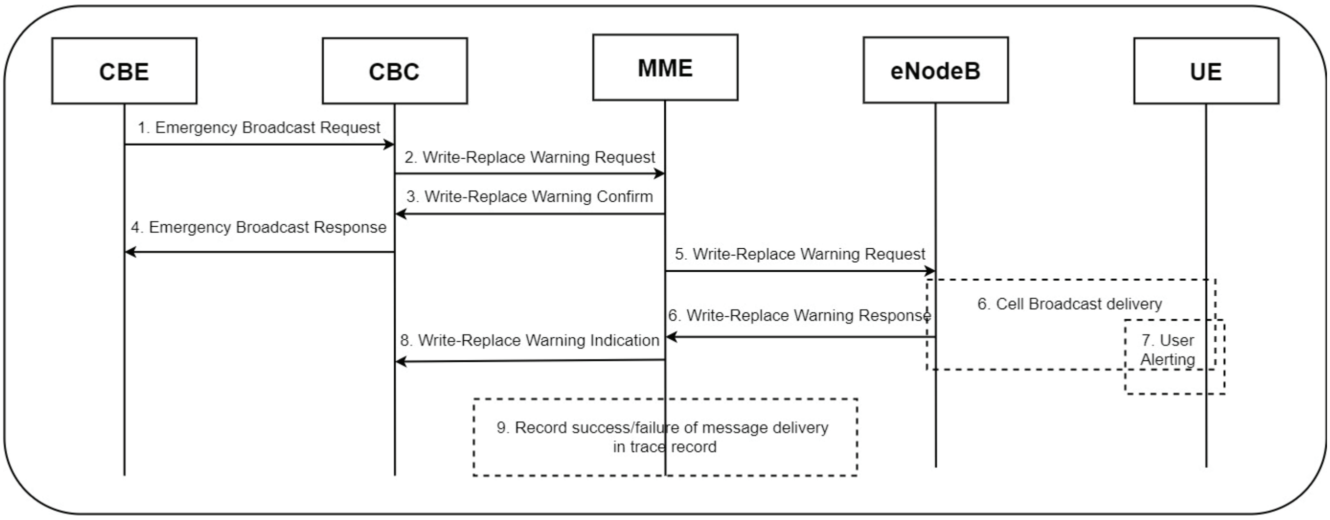


Fig. 4. The process for delivering the PWS warning message.

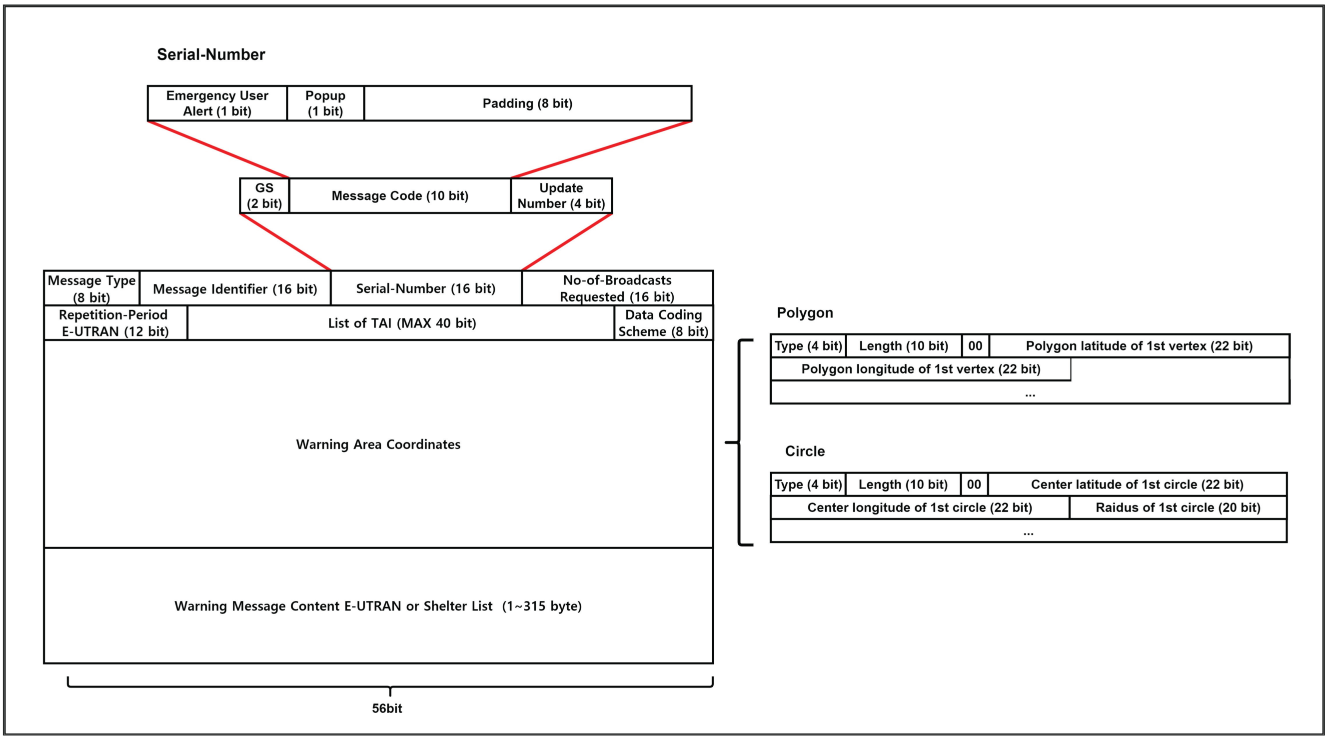


Fig. 5. The format of the warning message.

districts in Korea from the GIS sites. Then, the GAN in [21] was used to automatically generate the coordinate information for the broadcast area of the alert area. In GAN, U-Net, and PatchGAN are exploited for the generator and discriminator, respectively. To learn the least convex polygon generation model, this study generated a polygon image that includes the alert area that is labeled as image data. For the circle generate model, this study used a circle image, which includes the alert area. In this study, 2,992 images were used in order to learn the least convex polygon generation model and 768 images were used to learn the circle generation model. For the validation, 748 and 192 images were used for the least convex polygon generation model and the circle generation model, respectively. The parameters are listed in Table II. Fig. 6 shows the generation process of the coordination information. During the first step, the image of the target alert area was cropped. Second, the cropped image was provided as the generator input, and the least convex polygon generator (or circle generator) results in a polygonal (or circular) image, which includes the target alert area. Finally, the polygonal (or circular) image was converted into coordinate information.

TABLE II
THE PARAMETER CONFIGURATION FOR THE TWO MODELS.

| | Polygon model | Circle model |
|---|---|---|
| total dataset | 4675 | 1200 |
| dataset for learning | 2992 | 768 |
| dataset for validation | 748 | 192 |
| dataset for test | 935 | 240 |
| beta | 0.5 | 0.5 |
| batch size | 4 | 4 |
| epoch | 300 | 500 |
| loss_G | L1+original_GAN loss | L1+original_GAN loss |
| loss_D | original_GAN loss | original_GAN loss |
| optimizer | Adam | Adam |
| lr_G | 0.0002 | 0.0002 |
| lr_D | 0.0002 | 0.0002 |
| input image size | 256x256 | 256x256 |
| output image size | 256x256 | 256x256 |

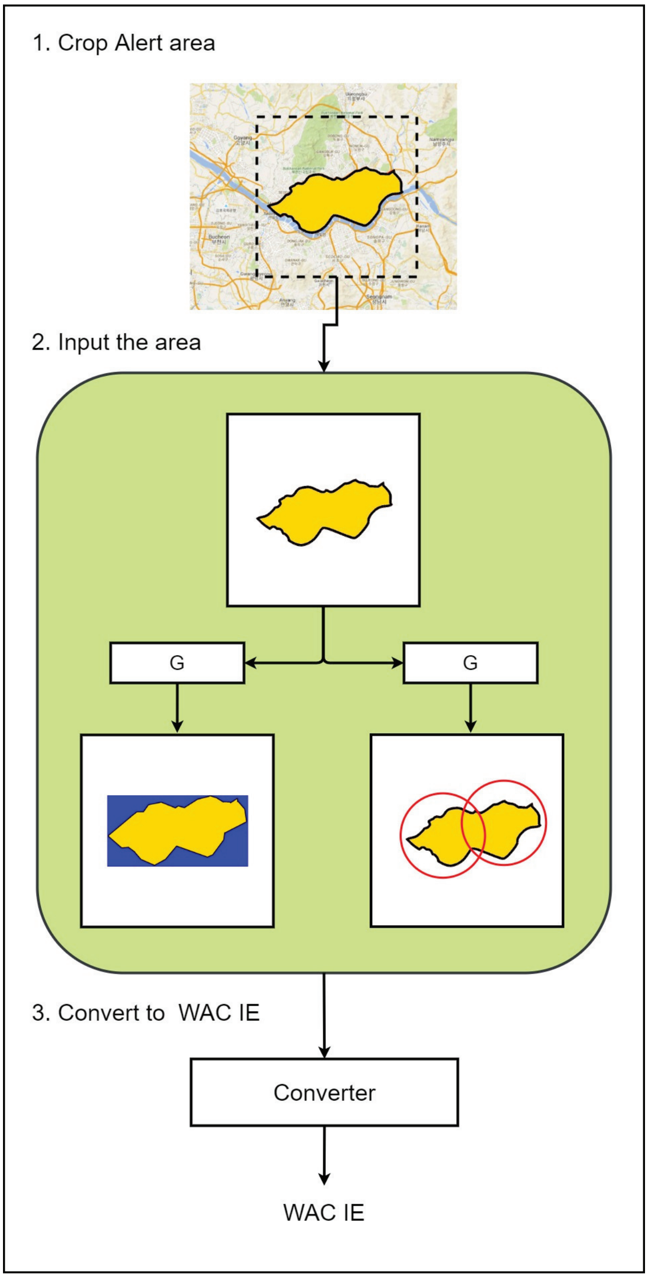


Fig. 6. The coordinate generation process.

## B. Warning Message Delivery System Modification

The proposed PWS provides additional warning information, such as public COVID-19 clinics and shelter for natural disasters. Fig. 7 depicts the sequence of the message delivery in the PWS. After receiving an emergency broadcast response, the CBE generates and transmits shelter broadcast requests. The CBE reuses the warning message information in the emergency broadcast requests to decrease the delay for the shelter broadcast request generation. The CBC forwards the received shelter broadcast request to the MMEs that already received the write-replace warning request. For the acknowledgement, the MME sends shelter broadcast confirmation to the CBC, and the CBC transmits the shelter-broadcast response to the CBE. During the cell broadcast delivery from eNodeB to UE, the shelter broadcast request, shelter broadcast confirmation, and shelter broadcast response are exchanged, and the delay for additional information delivery decreases. After transmitting the write-replace warning indication to the CBC, the MME sends a shelter broadcast request to the corresponding eNodeBs. An eNodeB conducts a shelter broadcast delivery to all the UEs. In the shelter broadcast delivery, because each eNodeB provides additional information such as shelter information based on the location and communication coverage of eNodeB, each eNodeB transmits different shelter information. Then, the UE displays the additionally received warning message on the screen.

This study modified the warning message format to provide additional warning information, as shown in Fig. 8. The contents of the second warning message depend on the location of the eNodeB. If a UE is located in an overlapping area, it receives several second warning messages from the different eNodeBs. Therefore, to identify the second warning message, this study defined eight unused bits in the message code as shelter identifiers. In the first warning message, the value of the shelter identifier field is zero because the shelter identifier is not used. In addition, this investigation defined the shelter list for the additional information that is on the second warning message. The shelter list contains up to three types of shelter information. The shelter information consists of the coordination fields (latitude and longitude of the shelter), the addresses for shelter, and the shelter names.

## C. Customized Information based on the User Location

The proposed PWS provides customized information for a smart device user based on its location. Algorithm 1 describes the process of the warning message customization based on the location. When a smart device receives a warning message, it checks whether the smart device is located in a polygon or a circle coordinate-based broadcast area. If the device is in the broadcast area, it checks the duplication of the warning message by using the message identifier and update number. If the smart device receives the first warning message, it informs the user of the warning message content. When the smart device receives the warning message with the same message identifier and update number, it checks whether it is the second warning message based on the shelter identifier. If the second warning message with different shelter identifiers

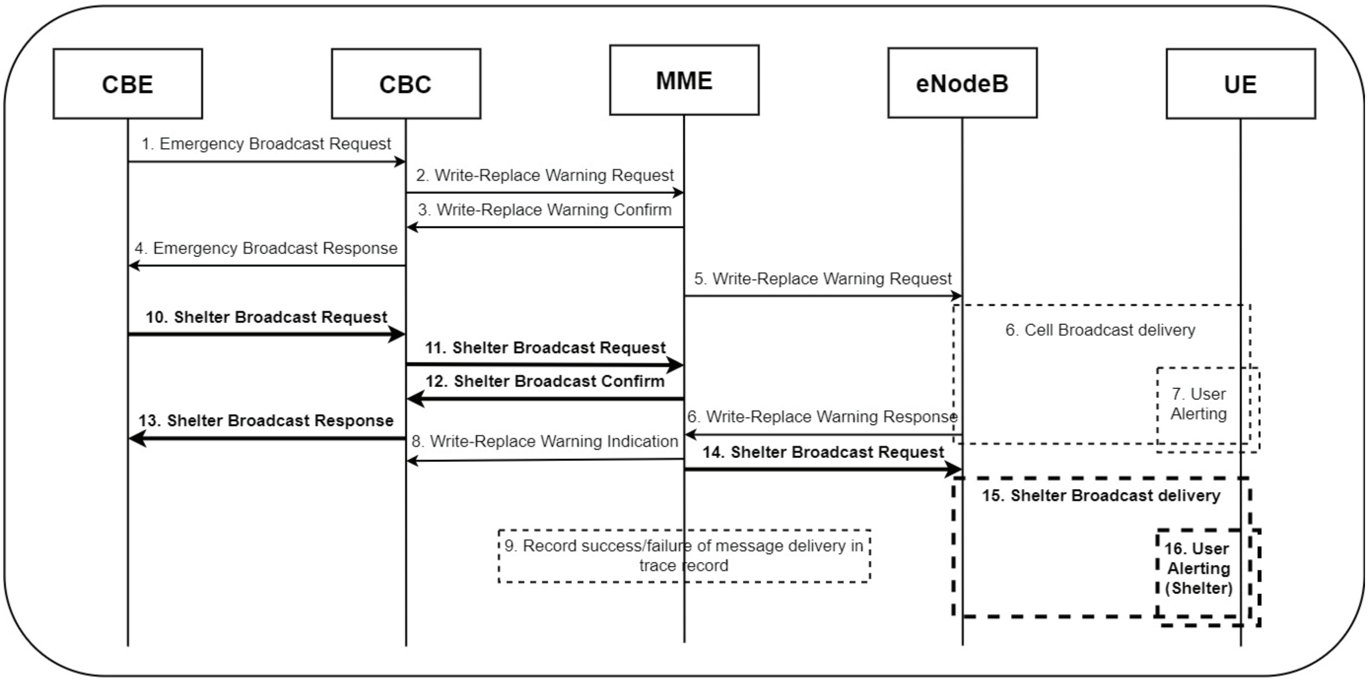


Fig. 7. The sequence of the message delivery in the enhanced PWS.

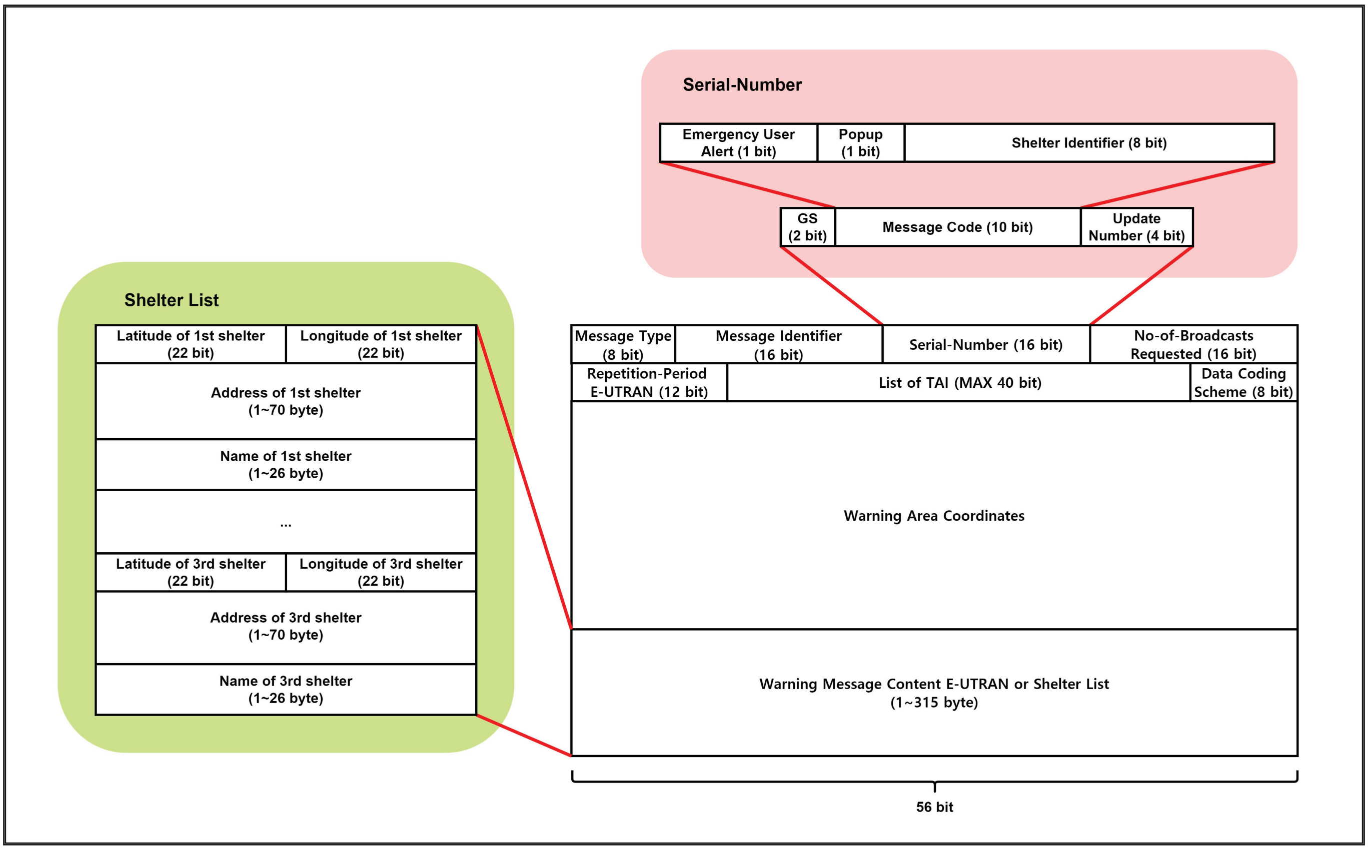


Fig. 8. Modification of the warning message format.

is transmitted, the shelter list is updated, and the timer starts to wait for the shelter information from the other eNodeBs. If the timer expires, the smart device informs the user of the location information of the three nearby shelters.

Fig. 9 shows an example of a customized warning message. As presented in the figure, a UE is located in an overlapped

**Algorithm 1** Algorithm for warning message customization

**if** receive warning message from eNodeB **then**
  **if** the smart device is located in broadcast area **then**
    **if** $\textit{message identifier}_{\text{new}} \neq \textit{message identifier}_{\text{prev}}$ or $\textit{update number}_{\text{new}} \neq \textit{update number}_{\text{prev}}$ **then**
      display the message content of the first warning message
      $\textit{message identifier}_{\text{prev}} \leftarrow \textit{message identifier}_{\text{new}}$
      $\textit{update number}_{\text{new}} \leftarrow \textit{update number}_{\text{prev}}$
      $\textit{shelter list}_{cur} \leftarrow empty$
      $\textit{shelter identifier}_{\text{new}} \leftarrow empty$
    **else**
      **if** $\textit{shelter identifier}_{\text{new}} \neq \textit{shelter identifier}_{\text{prev}}$ **then**
        $\textit{shelter identifier}_{\text{prev}} \leftarrow \textit{shelter identifier}_{\text{new}}$
        *extract shelter list*$_{\text{new}}$ from the warning message
        $\textit{shelter list}_{cur} \leftarrow \textit{shelter list}_{cur} \cup \text{shelter list}_{\text{new}}$
      **end if**

      **if** timer is stopped **then**
        timer starts
      **end if**
    **end if**
  **end if**
**end if**

**if** timer expires **then**
  display location information of three nearby shelters
**end if**

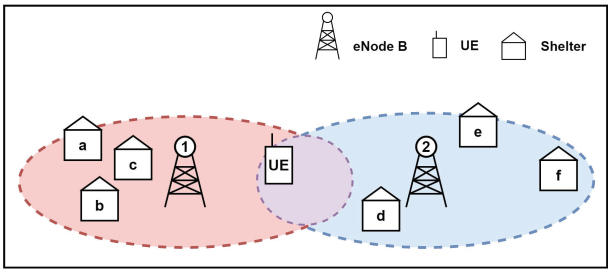


Fig. 9. Example of customized information based on the location.

area of two eNodeBs and it connects to eNodeB 1. The UE receives two warning messages from eNodeB 1 and eNodeB 2. When the UE receives a warning message from eNodeB 1, a shelter list is created, and the list is sorted by the distance between the UE and the shelter. The sorted shelter list orders are c, b, and a. When the UE receives a warning message from eNodeB 2, the shelter list is updated, and the list order is d, c, b, a, e, and f. If the timer expires, the UE informs the user of the location of shelters d, c, and b.

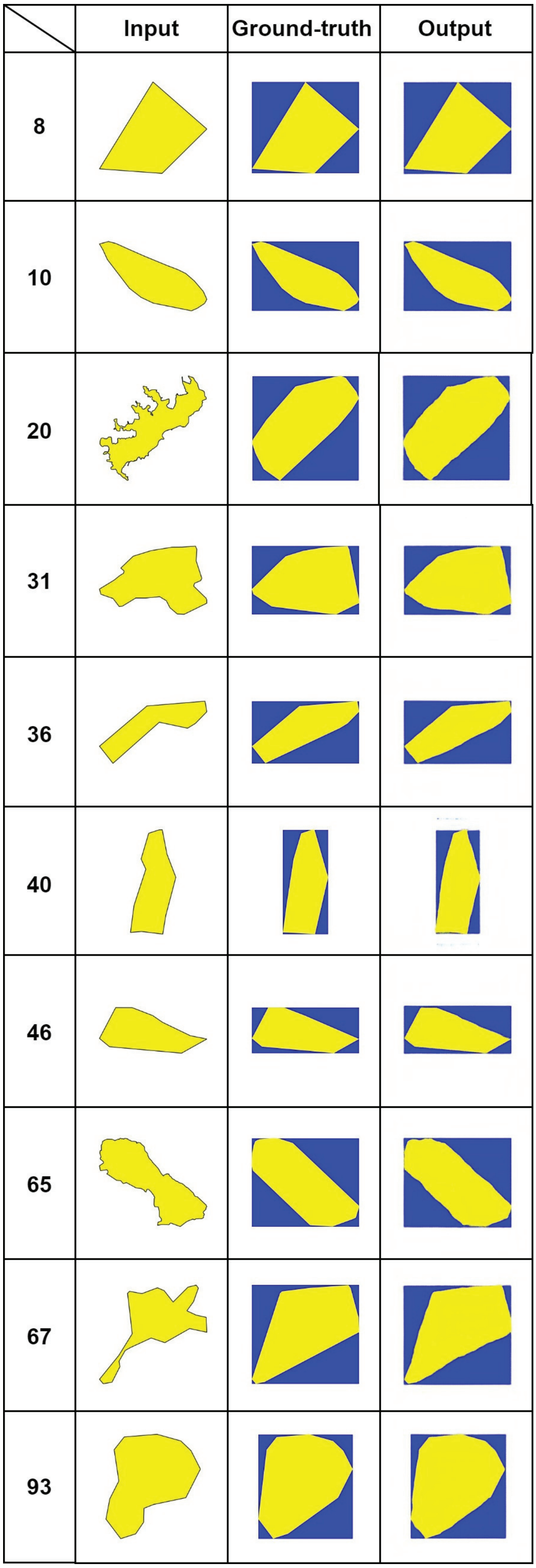


Fig. 10. The output image of the polygon generator.

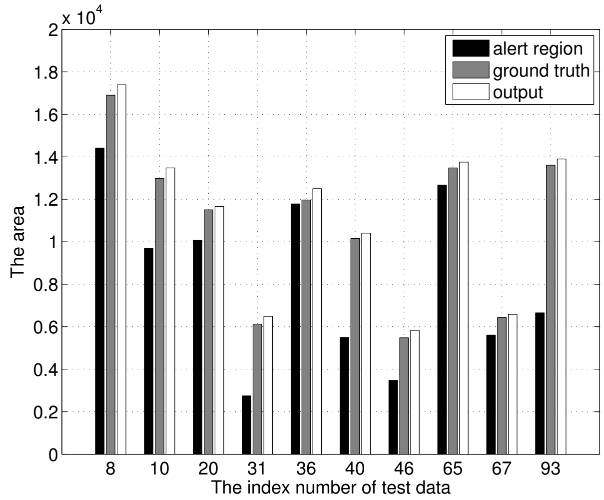


Fig. 11. Area of the output image of the polygon generator.

## IV. Evaluation

The proposed PWS was evaluated by examining the performance of the polygon generation and the circle generation models. Afterwards, the proposed PWS was implemented in order to verify its feasibility and to evaluate its functionality.

### A. Generation Model

This subsection describes the performance evaluation of the polygon generation and circle generation models. First, the performance of the polygon-based coordinate generation model is discussed. Fig. 10 shows 10 images for the alert area, ground truth, and output that is generated by the generation model. To evaluate the similarity of the ground truth and output, this study measured the area of the alert region, ground truth, and output image by using OpenCV [22]. In the results that are presented in Fig. 11, overshooting occurs in the ground truth and it generated an output image; however, the difference between the area of the ground truth and the output image is negligible. Second, this subsection discusses the performance of the circle-generation model. Ten output images of the circle-generation model are presented in Fig. 12. This investigation then measured the overshooting area of the output image of the circle generation model and compared it with the overshooting area of the ground truth. In Fig. 13, results show that the areas of the output image and ground truth are similar.

Fig. 14 represents the average ratio of the overshooting area for the ground truth and the output image to the alert area. The x-axis and y-axis represent the type of warning that is coordinated and the average ratio of overshooting to the alert area, respectively. In the polygon coordinates, the average ratio of the ground truth and output is approximatedly 134% and 137%, respectively. In the circle-based coordinate, the average ratio of the ground truth and output to the alert area is 192% and 222%, respectively. this means that the area of the output image is approximately 13% wider than the ground truth.

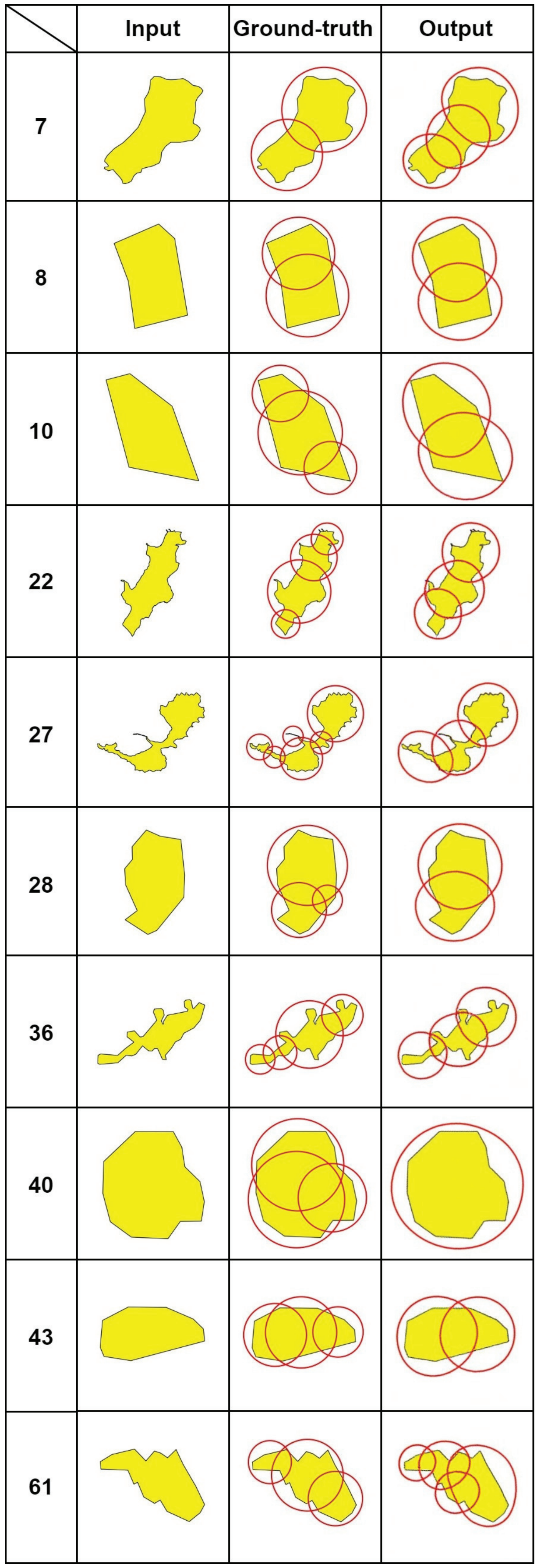


Fig. 12. Output image of the circle generator.

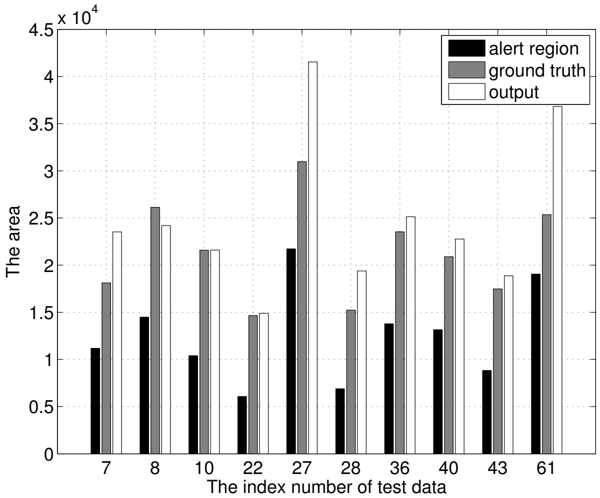


Fig. 13. Area of the output image of the circle generator.

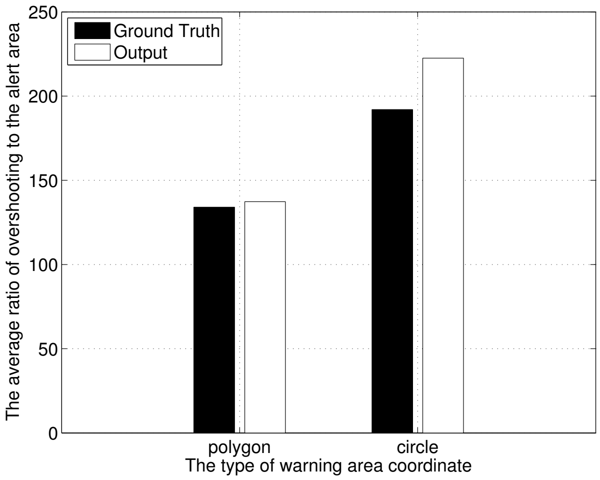


Fig. 14. The average ratio of the overshooting area.

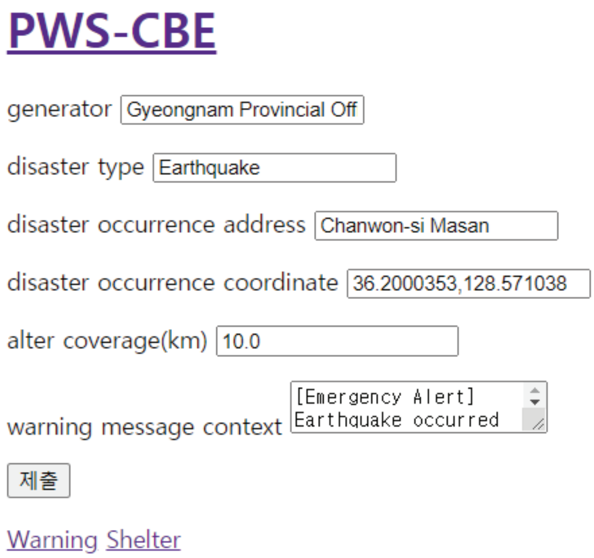


Fig. 15. Implementation of the CBE.

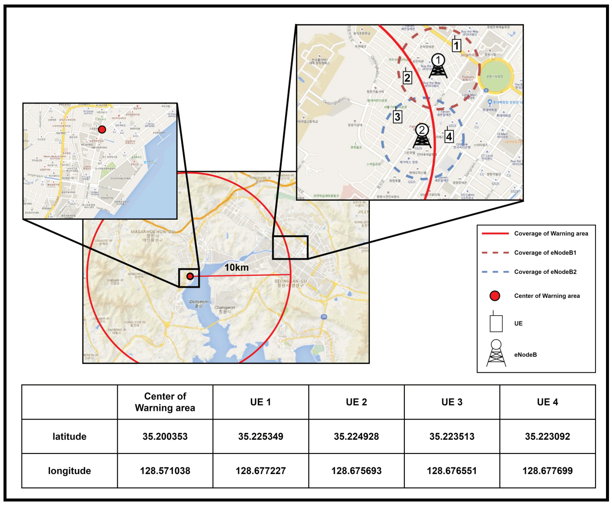


Fig. 16. Evaluation scenario.

### B. Feasibility Evaluation of the Proposed PWS

This subsection validates the functionality and feasibility of the proposed PWS. For the validation, this study implemented five components in the PWS: CBE, CBC, MME, eNodeB, and UE. Node.js was used to implement the CBE [23]. As depicted in Fig. 15, the web page of the CBE component generates a disaster event and a warning message. The CBC, MME, and eNodeB components were implemented by using Java, and the UE component was implemented as an Android application. The UDP is used for communication from CBE to eNodeB and from eNodeB to CBE, and the communication between eNodeB and UE uses TCP.

The following describes the evaluation that was performed. As shown in Fig. 16, it was assumed that an earthquake occurs at a point with a latitude value of 35.200353 and a longitude value of 128.571038. A warning message is transmitted within a 10 km radius around the epicenter. Because eNodeB 1 and eNodeB 2 are located in the broadcast area of the warning message, they send warning messages to four UEs. As mentioned above, when a UE receives a warning message, it checks whether the UE is located within the broadcast area based on the broadcast area and its location. In this scenario, because UEs 2 and 3 are located in the alert area, they inform the user of the alarm. UEs 1 and 4 also receive the warning message but they do not notify the warning message because they exist outside the alert area. Fig. 17 illustrates an alarm example of a warning message.

## V. Conclusion

An enhanced PWS is proposed in this investigation. To automatically generate the coordinates of the broadcast area for the warning messages, the least convex polygon generation model and circle generation model were proposed by using a GAN. For the warning message customization, this study


Fig. 17. Warning message alarm in a smart device.

provides additional warning message information, such as clinics and shelters. To achieve this, an enhanced warning message delivery system is proposed along with a customized alarm algorithm. The proposed generation models were evaluated based on the overshooting area measurements. For the enhanced warning message delivery and a customized alarm system, the proposed system was implemented on a desktop and an Android device, and a test scenario was conducted.

## REFERENCES

[1] "National disaster and safety portal," South Korea. [Online]. Avaiable http://eng.safekorea.go.kr/ Accessed on: Jan. 27. 2021.

[2] S. Yi, S. Chun, Y. Lee, S. Park, and S. Jung, *"Radio protocols for LTE and LTE-Advanced,"* Singapore, Singapore: John Wiley & Sons Singapore Pte. Ltd., 2012.

[3] ATIS, "Feasibility study for WEA cell broadcast geo-targeting," Dec. 2015.

[4] 5G Americas, "Public warning systems in the Americas," Jul. 2018.

[5] ETSI, "3GPP TS 22.168 v8.1.0 Release 8," Jan. 2009.

[6] ETSI, "3GPP TS 22.268 v9.2.1 Release 9," Jun. 2009.

[7] FCC, "The commercial mobile alert system," Feb. 2013.

[8] ETSI, "3GPP TS 23.041 v9.4.0 Release 9," Jun. 2010.

[9] ETSI, "3GPP TS 23.041 v16.4.0 Release 16," Jul. 2020.

[10] ETSI, "3GPP TS 29.168 v15.1.0 Release 15," Sep. 2018.

[11] ETSI, "3GPP TS 36.413 v15.6.0 Release 15," Jul. 2019.

[12] ATIS, "ATIS 0700041 wireless emergency alerts (WEA) 3.0: Device-based geo-fencing," May 2019.

[13] A. Garg *et al.,* "Smart geo-fencing with location sensitive product affinity," in *Proc. ACM SIGSPATIAL*, 2017.

[14] ATIS, "Joint ATIS/TIA CMAS alert gateway to CMSP gateway interface specification," Dec. 2012.

[15] X. Zhang *et al.,* "Architecture design of electric power emergency communication based on 4G LTE network," in *Proc. IEEE ICCCBDA*, 2019.

[16] G. Baldini, T. Sturman, A. Dalode, A. Kropp, and C. Sacchi, "An emergency communication system based on software-defined radio," *EURASIP J. Wireless Commun. Netw.*, vol. 2014, no. 1, pp. 1–6, 2014.

[17] F. Volk, R. T. Schwarz, M. Lorenz, and A. Knopp, "Emergency 5G communication on-the-move: Concept and field trial of a mobile satellite backhaul for public protection and disaster relief," *Int. J. Satellite Commun. Netw.,* vol. 2020, pp. 1–4, 2020.

[18] Z. Kaleem *et al.,* "UAV-empowered disaster-resilient edge architecture for delay-sensitive communication," *IEEE Netw.*, vol. 33, no. 6, pp. 124–132, 2019.

[19] C. H. Lee, I. Orikumhi, C. Y. Leow, M. A. B. Malek, and T. A. Rahman, "Implementation of relay-based emergency communication system on software defined radio," in *Proc. IEEE ICPADS*, 2015.

[20] "GIS DEVELOPER," [Online] Available: http://www.gisdeveloper.co.kr, Accessed on March 4, 2021.

[21] P. Isola, J.-Y. Zhu, T. Zhou, and A. A. Efros, "Image-to-Image translation with conditional adversarial networks," in *Proc. IEEE CVPR*, 2017.

[22] "OpenCV," [Online] Available: https://opencv.org/, Accessed on March 5, 2021.

[23] "Node.js," [Online] Available: https://nodejs.org/ko/, Accessed on: March 5, 2021.

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