Design and Implementation of Geo-Social Information based Personalized Warning Notification System

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Abstract

In case of a emergency situation or a natural disaster, a warning notification system is an essential tool to notify at-risk people in advance and provide them useful information to survive the event. Although some systems have been proposed such as emergency alert system using android, SMS, or P2P overlay network, these works mainly focus on a reliable message distribution methods. In this paper, we proposed a novel design and implementation of a personalized warning notification system to help inform not only the at-risk people but also their family and friends about the coming disaster as well as escape plan and survival information. The system consists of three main modules: the user selection module, the knowledge based message generator, and message distribution modules. The user selection module collects the list of people involved in the event and sorts them based on their level of involvement (their location, working position and social relationships). The knowledge based message generator provides each person with a personalized message that is concise and contains only the necessary information for the particular person based on their working position and their involvement in the event. The message distribution module will then find a best path for sending the personalized messages based on trustiness of locations since network failures may exist in a disaster event. Additionally, the system also have a comprehensive database and an interactive web interface for both user and system administrator. For evaluation, the system was implemented and demonstrated successfully with a building on fire scenario.

■ keywords : Disaster Warning System, Location Trustiness, Geographical Failure, Software Defined Network

I. Introduction

Nowadays an emergency event such as a natural disaster or a building on fire may occur any time. In such event, a warning notification system is used to inform the at-risk population of the coming danger and provide them with useful information to escape the dangerous area. Accordingly, there is a strong demand of developing a warning notification system, which sends warning messages containing useful advice and survival information as fast as possible to the people in emergencies.

Recently, some researches are conducted to develop an efficient emergency alert systems. In [1], an emergency alert system using android was developed in which bulk messages were split to avoid network congestion, hence solving the problem of sending a large number of notification messages. Regarding the problem of sending notification alert in rural area, a SMS-based rural disaster notification system was studied in [2]. Similar to SMS, in [3] and [4], the Cell Broadcasting Service (CBS) is used to distribute warning message over mobile network. Instead of using mobile network, the GSFord system proposed in [7] built a robust geo-aware P2P overlays to

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successfully deliver notification message in extreme situations.

The previous works mainly focus on message distribution methods in emergency event [14,15,16]. However, the warning notification system must be considered sufficiently with three main processes: the at-risk user selection, the message generation and the final message distribution process. The at-risk user selection process not only involves collecting the people inside the dangerous area but also the people who are related to the event or have social relationship with at-risk people. The content of the warning message must be concise and personalized for a particular recipient. One recent method to personalize the warning message is the knowledge based message generator [5]. The knowledge based generator creates messages for each target user and the user who are indirectly related to the event such as someone who may assist target user or who have a closed relationship with target user. The message distribution process also need to considered carefully since there may be network failure during the emergency event. One noble recently work which solves the problem of message dissemination is the calculation of trustiness of location [9]. In order to develop a complete system, all of the three processes must be consider carefully. In this paper, we proposed a novel design and implementation of a personalized warning notification system to improve the efficiency of emergency notification. The system consists of three main modules: the user selection module, the knowledge based message generator and message distribution module. To support user and system administrator, the system also equips with an interactive web interface and a comprehensive database.

The rest of the paper is organized as follows: we describe the main rationale of the proposed system in section 2. In section 3, we present the detailed design of our Personalized Warning Notification System. Section 4 describes the implementation and evaluation of the proposed system. Finally, we conclude this paper in section 5.

II. Rationale of the System

Recently, warning notification system have been received special attentions from researcher around the world since natural disaster becomes more and more extreme. Some systems were proposed, and mostly fall into one of four categories: warning notification system based on SMS service [1,10,12], warning notification system based on the next generation mobile network [3,4], warning notification on android smartphone based on Internet service [2,11,13], and warning notification system based on P2P overlay network [7,8]. The previous work mainly focus on the message dissemination process during an emergency situation. However, the content of the warning message itself and its recipient are lack of careful consideration.

In order to develop a fully functional warning notification system, the three main questions must be considered cautiously: who need to be warned? What information should we provide them? How can the warning message reach its recipient?

For the first question, the previous works only consider the directly affected user, who are currently inside the dangerous region. This consideration is not sufficient since their family and closed friends also have the desire to know about the emergency situation. In some case, the family and friend can make a better contact with the person in danger and help them escape.

For the second question, the previous works only send the same information to everybody. However, each person might be in a different situation. For example, in an earthquake, some people might be trapped in a building while others are on the street. Therefore, there is a strong need that the warning message is personalized to its recipient situation.

How the warning message can reach the recipient is the question that previous works focus on. However, a disaster can cause severe damage to the communication system network. Therefore, some area could be unable to receive SMS or connect to Internet service, hence lead to the failure of warning people in the area. One way to mitigate the issue is to build an P2P overlay network as in [7,8]. Such overlay network can be further improve by using the trustiness of the location [9] to determine which route the message should go.

In this paper, we proposed a novel design and implementation of a personalized warning notification system to improve the efficiency of emergency notification. The system was designed to answer the three mentioned questions with three corresponding main modules: the user selection module,

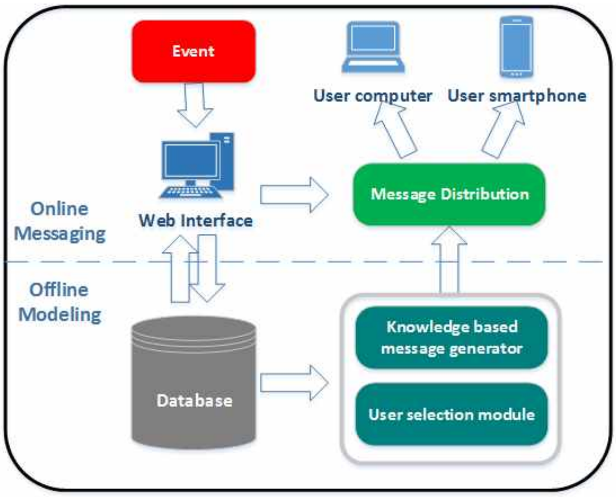

Figure 1. The General Architecture of the Personalized Warning Notification System

the knowledge based message generator and message distribution module.

III. Personalized Warning Notification System

1. System Architecture

Our proposed system consists of two main parts: offline modeling and online messaging as depicted in Figure 1. The offline modeling is where the event analyses and message personalizations are made, while the online messaging is where the actual interaction between the system and the users happens. In the online messaging part, we have an interactive web interface and the message distribution module. The web interface lets the users interact with the system as well as to help the system administrator manages the personalized warning notification system itself, while the message distribution module has the key responsibility to maintain a reliable connections between the system and each users to ready for emergency message dissemination when necessary. In the offline modeling, we have the user selection module and the knowledge based message generator as well as a database to support the operation of the two modules. The function of user selection module is to choose the right people who must receive the warning notifications, while the knowledge based message generator creates the right message for them.

Whenever an event happen, the information about the occurred event will be updated into the system database via the web interface. After that, the offline modeling is begun, and the event information will be collected and analyzed by the user selection module. Based on the event information from the database, the User selection module selects the users who are related to the event, by using their current location, working positions and social relationship. The selected user will be stored in a list which contains the user id of a user to whom we need to notify and generated message for that user. The list which is generated by the user selection module will be input into the knowledge based message generator, which then computes the relative users and event related information to generate a warning message based on defined rules. Each message provides the useful information for a particular recipient such as how to get overcome the happening events, what emergency contacts are there, or who are in dangerous area. Output of knowledge based message generator is a collection list of users and their corresponding generated messages. The list is then transferred to the message distributor module to notify users. Since network failure might exist due to the impact of a disaster, the message distributor must rely on the trustiness of location to find the best route to deliver message to user.

2. User Selection Process

The user selection process involves finding the right people to notify about the emergency situation. The first people on the list should be those who are currently inside the dangerous area. With the rapid development of social network, people want to know about the status of their friends and family and hence they should be notified when their loved ones are in danger. Moreover, some people who are not currently in the affected area but they have ability to assist someone inside the area. Those people should also be informed about the dangerous situation of the ones that they can help. In the proposed system, we conduct two phases in the user selection process, which are the user selection based on event location and user selection based on social relationship.

In the first phase, we choose the user selection based on the affected area of the emergency event. In order to do that, we need to gathered the user's current location periodically. One major issue of the first phase is that most users are not just standing still but usually moving with different speeds. If user is driving fast, they may go from inside the affected area to the outside while because of a long data gathering interval, the system still thinks that users are in danger. The opposite situation might also happen when a user run from the safe regions into the dangerous one but the system does not notice. One way to mitigate the issue is to increase the data gathering interval. However, it might violate users' privacy since their locations are continuously updated to the system. A tradeoff between users' privacy and the accuracy of the system has to be made.

In the second phase, we further find the user with closed relation or ability to assist those selected users in the first phase. This phase can be done by analyzing the user social network to find family members and closed friends and colleagues. A utility called 'Friends-based notifications' is provided to help users to keep track of their friends and loved ones. For example, a user will receives an alert when the system detects his best friend is at the disaster region.

3. Knowledge based Message Generator

The knowledge based message generator is responsible for generating the customized message for each person based on the output of the user selection module, user type and event informations. In order to do that, the module requires a big collection of defined rules and detailed information of both users and the emergency event. Therefore, a comprehensive design of database is essential for this module to work flawlessly. The design of our database is shown in Figure 2. The database is designed to store information about the registered user and event, as well as spatial information about the user and the disaster. The user information (id, location, contact information, personal information, etc.) is saved in user database. Disaster information (preliminary caution, evacuation routes, helplines, etc.) is saved in disaster database. The message schema is dedicated to store message templates for each user type and also store the collection of defined rules for the knowledge based message generator. The three database schemas are designed to make it easy to explore the whole related data with an id of a

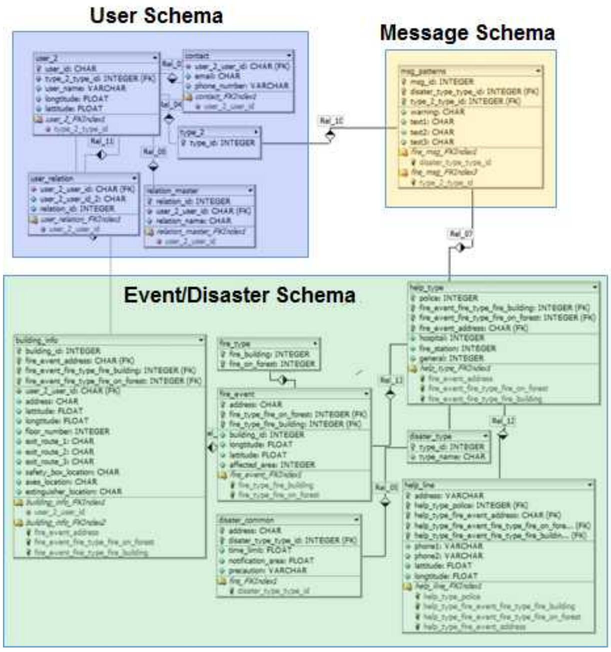

Figure 2. Design of the database

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Input     A: notification area
          U: user data set
          D: disaster data set
Output    ∀_{i∈U_total} P(u_i, msg_i)

#The list of user and message pair who are related to an event.

START
  U_A = list of users who found in A
  U_S = list of users who are safety in charge for A
  U_subscription = list of users who are interested in A
  U_A relations = list of users who are related to U_A
  U_total = U_A ∪ U_S ∪ U_subscription ∪ U_A relations
  FOR each user in U_total
       SET_UTYPE(u_i) {
            IF (u_i ∈ U_A) THEN U_TYPE = TARGET_USER
            ELSE IF (u_i ∈ U_S) THEN U_TYPE = SAFETY_INCHARGE
            ELSE IF (u_i ∈ U_A relations) THEN U_TYPE = USER_RELATIVE
            END IF
       }
       msg_i = msgGenerator(u_i, D, LEVEL 1, U_TYPE)
  END FOR
STOP
```

Figure 3. Knowledge based Message Generation Algorithm

user involved in an event.

Knowledge based message generator not only creates the message for target user, but also for the users who are indirectly related to an event or users who may help target user to get over from affected area of an event. The algorithm behind the knowledge based message generator is presented in Figure 3. When an event happen the event information is provided to system, the system uses the event information to provide input to the knowledge based message generator such as notification area. Knowledge based message generator uses provided event information together with user data set and disaster data set as input to generate a notification message. Knowledge based message generator filters out the users to whom we need to notify about the event and lists out the users who are in the affected area of an event (target user), users who are interested in or subscribed for the location where the event is happening (interested user), the friends or family members of target user (user relative) and users who are responsible for safety for an event (safety in charge). These filtered users are categorized according the user type. Then different message contents are generated for different types of user. Then the knowledge based message generator creates the list of user and message pair. The list of user and message pair contains the user id of a user and the appropriate message for that user. The list generated by knowledge based message generator is used by message administrator to notify proper user with proper message contents.

4. Message Dissemination

The most important in a disaster warning notification system is quickly delivering reliable warning message to the relevant users who can be affected or correlated by the disaster event. For example, when a building on fire happens, a man who is inside this building need to quickly find out an exit. A late or wrong choice at this time may lead him into an irredeemable situation. Therefore, sending quickly information to help him making a decision is very important.

In fact, when unexpected disasters such as earthquake events happen, the networks may get catastrophic impacts, e.g. link failures. In this situation, to send a message to the user, we might have to reroute the message to another router. To address this problem, we have researched on reliable overlay network construction which is resilient to geographical failures [7][8]. The constructed overlay network can be used as a communication mean for disseminating warning messages. In these works, we used the proximity aware techniques including Proximity-M and Proximity-T to improve the reliability of message dissemination. under various scales of geo-correlated failures with different overlay networks. s reliability of message dissemination substantially. However, these technique requires the router information and it is hard to realize in the current internet.

Fortunately, SDN (Software Defined Networking) is promised as future of internet which provides centralized network management. SDN can provide detail information of underlay routers and make a decision based on the global view of the current network condition. The problem is that how to obtain the current status of the network in disaster situations. To achieve this goal, we studied on location trustiness which can directly affect to network infrastructure in disaster situations. Based on that we calculate the trustiness of links and switches to provide information for rerouting in SDN controller. By this way, our dissemination module manages a highly reliable overlay network, which quickly and reliably disseminates a warning message to all the target users.

In our previous work [9], we proposed a method of calculating trustiness of location based on multimodal information. To calculate trustiness of location, we first define a geo-mapping matrix (called GMM), then calculate the impact of disaster events on each cell of GMM by using earthquake information and sensor data. A cell of this matrix has a size $c \times c$ with c can be a real number describing the length by kilometer. When an earthquake event happen, a matrix trustiness of location T^e = $[T_{i,j}]_{K \times K}$ is generated based on its magnitude and location, in which K is the size by cell of the matrix. In our approach, the impact of an earthquake is decreasing linearly with the distance from epicenter to a location. The trustiness of location for each cell of T^e is calculated as follows:

$$T_i = \begin{cases} 1 - \dfrac{M}{\delta} & \text{if } i = 1 \\ T_{i-1} + \dfrac{M}{\delta \times R} & \text{if } i > 1 \end{cases} \quad (1)$$

where i is a number of integer that shows the distance by cells from epicenter cell (i=1) to R on the GMM, R is a number of integer and R = $K/2 + 1$; δ is a threshold of magnitude to set trustiness value equals 0 ($M \geq \delta$). Here, a location $L_{i,j}$ can be affected by a set of the earthquakes $e = \{e_1, e_2, .., e_n\}$. Our approach based on averaging trustiness value of that cell on the matrix as follows:

$$T_{i,j} = \frac{1}{n} \sum_{k=1}^{n} T_{i,j}^{k} \quad (2)$$

where $T^{n}_{i,j}$ is the trustiness of location at $L_{i,j}$ after earthquake event e_n happened.

In another approach, we assume that several cells on the GMM have n kinds of sensors, e.g., temperature sensors and fire sensors. Each of them has m_i sensors with weighted w_i that indicates a degree of influence by kind of disaster. The location trustiness for each cell which has the disaster sensors is formulated as follows:

$$f_{(x)} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{j=1}^{m_i} w_i x_{ij} \tag{3}$$

where x_{ij} is trustiness of location which calculated from a sensor (see more details in [9]).

The combination of these two approaches can make reliability the trustiness of location. Let T_D is the trustiness of location which is calculated based on disaster information such as earthquake events, T_S is the trustiness of location using sensor-based ($T_S = f_{(x)}$). Thus, the trustiness of location T_L on a cell is defined as follows:

$$T_L = w_D T_D + w_S T_S \tag{4}$$

where w_D is the weight for trustiness of location T_D, w_D is the weight for T_S and $w_D + w_S = 1.0$.

According to the trustiness of location, in this work, for the purpose that is a reliable message dissemination we present how to apply it for rerouting in SDN when the network affected by disaster events. To do this, we build a module for managing the network topology which is used to deliver the messages to the users. In this module, we also generate a geo-mapping matrix, but it covers only the geographical of the network infrastructure. We identify the trustiness of switches or links based on its location on the GMM. The trusted value for each switch is the trustiness of location where it is located. For each link on the topology, the trusted value is assigned based on the averaging trusted value of the locations on the GMM in which a link crossed. An example of location trustiness on GMM and a network topology are shown in Figure 4.

Next, we take into account the problem of calculating the trusted value of a link L_i in the network topology based on

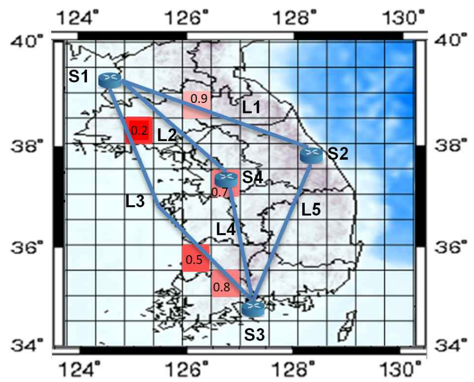


Figure 4. An example of mapping location trustiness and a network topology to GMM

location trustiness. A link L_i in the network topology can be represented by a polyline. We treat a polyline as a single object, including component segments. Each line segment is identified by two points: source location and destination location. So, we can make the line y between two that points. Next, we consider the finding all cells in which the trustiness of location is less than 1.0 and the line y is crossing. If no cells can be found the trusted value for L_i is 1.0. Otherwise, the trusted value of L_i in the network topology is defined by the averaging trustiness of location from all cells that link affected by the disaster events.

$$T_{L_i} = \frac{1}{n}\sum_{k=1}^{n} T_k \tag{5}$$

where T_k is the trustiness of location at the cell in which has trusted value less than 1.0 and the link L_i crossed.

To apply the trustiness of location in SDN controller, we implement a module that calculates continuously and update the trust value of the links into the database. Then, we install a module in SDN controller that is used to monitor the trust value of each link in the network topology. These values are used to change the routing table whenever a link or a switch affected by disaster events. In that case, a higher trusted value to be the priority instead of the shortest path.

IV. Evaluation

1. Interactive User Interface

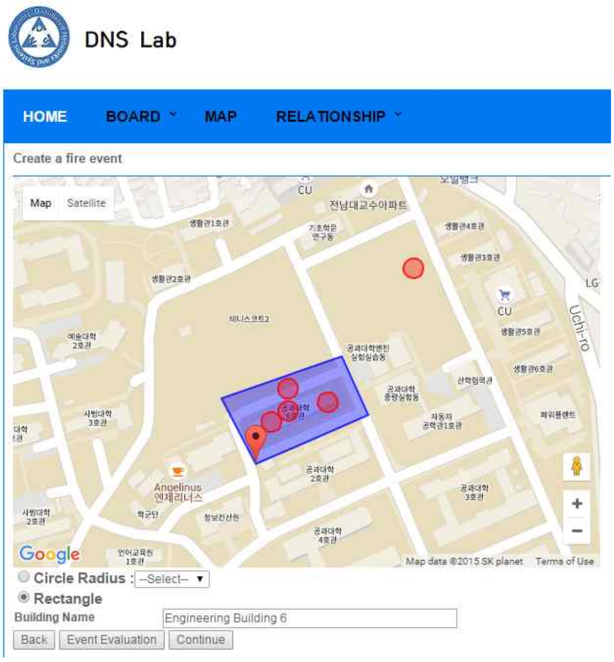


Figure 5: Create a new event from the web interface

Web interface is designed for registering user, event and to notify the warning messages to the users. It resembles a social network where user can register a new account and then connect to their friend and family, update their current location and subscribe an interest area. As a warning notification system, it also has ability to create and manage emergency event. An example of an emergency event is a building on fire event as shown in Figure 5. All we need to do is to specify the affected area and provide other event information, then press the Event Evaluation button. The evaluation actually happens at the user selection module and the knowledge based message generator. When the evaluation is done, press Continue button to start the message dissemination process.

2. User Selection Analysis

In this section, we analyse the two key parameters that affect the accuracy of the user selection process that are the data gathering interval and the user's speed in two experiments. The first experiment studies the impact of the data gathering interval, while the second one studies the effect of user's speed.

In the first experiment, each user moves with speed of 6 m/s and the gathering data interval is varied from 10 second to 60 second. Figure 6 shows the impact of gathering user's

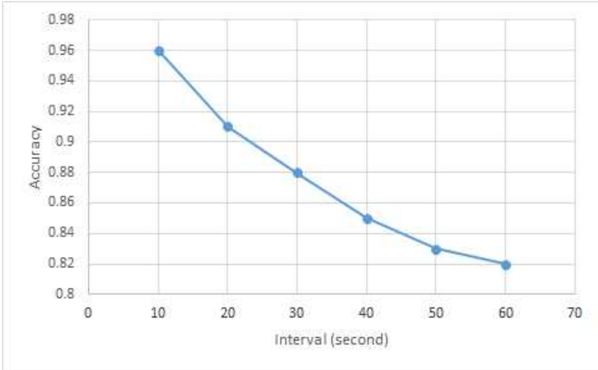


Figure 6: The accuracy of user selection process vs time interval

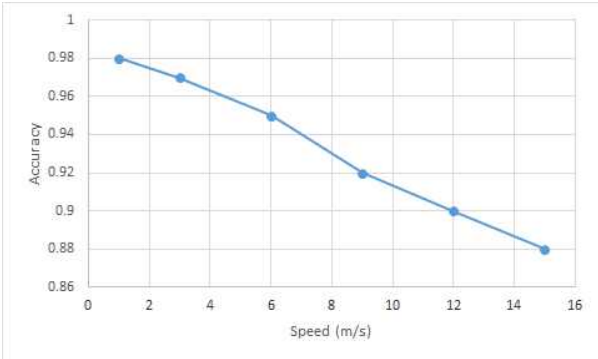


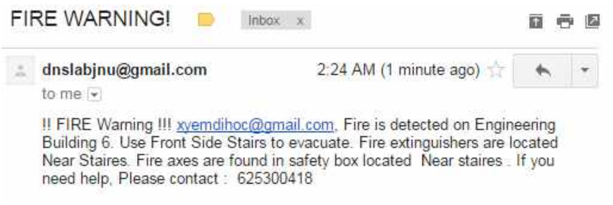
Figure 7: The accuracy of user selection process vs user's speed

location interval to the accuracy of the user selection process. It can be seen that as the interval increase from 10 to 60 seconds the accuracy of the user selection process decrease 17% from 0.96 to 0.82. The interval should be choose as small as possible.

In the second experiment, the data gathering interval is set at 10 second, and all users move with the same speed that varies from 1 to 15 m/s. The obtained result is depicted in Figure 7. As can be seen from the figure, the user's speed also have significant impact to the accuracy of the user selection process. When the speed of users increase from 1 to 15 m/s, the accuracy decreases dramatically 10% from 0.98 to 0.88.

3. Message Generation

Figure 8 presents the results of the personalized message generation process. As can be seen that target user received a message which contains essential information such as location of the disaster, which way to escape, where to find useful tool and emergency contact. In contrast, the family member of the



(a) A personalized message of a target user.

(b) A personalized message of target user's family

Figure 8: Sample personalized messages

target user only need to receive a warning that their loved one is in danger, and emergency contact to get in touch with the authority.

V. Conclusion

A disaster warning notification system is essential in emergency event to immediately provide at-risk people with useful information for dealing with emergency. To this end, we proposed the design and implementation of a personalized warning notification to help inform not only the at-risk people but also their family and friends about the coming disaster as well as escape plan and survival information. For future work, a highly reliable method based on trustness of locations to deliver warning message in a timely constraint where network failures exits can be developed for SDN network.

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