Towards a Reliable and Personalized Disaster Warning System

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***Abstract*—The main goal of a disaster warning system is preventing loss of properties by providing suitable information to people who can be affected by disaster events. The challenges of a disaster warning system are geographically correlated characteristics of disaster events and user movements, multimodal communication channels of social connectivity, and unexpected large scale failures caused by disasters. To deal with the challenges, in this paper we propose a new design of a reliable and personalized disaster warning system to support city-wide mobile users. The proposed disaster warning system has three main components, namely, personality-aware location prediction, geo-social connectivity aware message generation, and failure-resilient geo-aware dissemination. Through the preliminary evaluation of each component, we show that the viability of the proposed disaster warning system.**

Keywords-Disaster Warning System; Mobile Users; Geo-Social Information; Geographical Failure; Personality; Location Prediction

I. INTRODUCTION

The main goal of a disaster warning system is preventing loss of properties by providing suitable information to people who can be affected by disaster events [2][7]. To achieve this goal, the system should analyze the impact of disaster events in detail, pick up all relevant people to the disaster, prepare proper messages and send the messages reliably in timely manner.

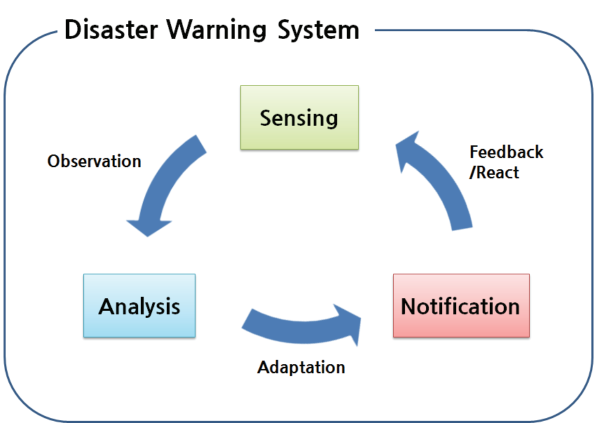

Figure 1. A conceptual view of a Disaster Warning System

Figure 1 illustrates a conceptual view of a disaster warning system. There are three basic components: sensing, analysis and notification. The sensing component continuously gathers information related to events, as well as users. The information related to events can be gathered by reading various sensors which are deployed on interesting locations [1][2] or getting the reports of events provided by local or government organizations. The information related users can be gathered through an interactive disaster portal or disaster warning notification applications. The interesting locations of users keep changing along with their current locations and the change of social connectivity. For example, if a user makes a new friend, the location of the new friend may be his new interesting location. Also, the information related to disaster event needs to be managed continuously. For example, the utility of hospitals, the traffic situation and failures of utility services need to be observed seamlessly in prior an event, and the system uses the information at the moment of the event.

The continuous observation, which is gathered by the sensing component, is used as an input of the analysis component. The role of analysis component is sorting out the most relevant users to the corresponding event and generating proper messages for each user. Because a disaster event is usually tightly coupled to geography, the location information of users and the interested location information of users are essentially required at this component [7]. If the system can predict the further location of a user based on the continuous observation, the analysis component also uses this location prediction for sorting out the relevant users. Beside the location information, the social connectivity is also very important for finding relevant users. For example, parents of elementary students desire to get the messages whenever their children can be affected by a disaster event.

Another role of analysis component is proper message generation. One of eventual goals of a disaster warning system is maximizing the coverage of warning message propagation. To achieve this, the warning system should pick better seeds of message propagation. Though the disaster warning system only uses the internet connection or SMS (Short Message Service), the message channel between end users are very diverse from phone call to human contact [6]. This multi-modal channel characteristic should be considered during selecting message seeds. In the aspect of effectiveness of the message, the message should have rich information for each user. By using the continuous observation, the system generates the proper message for each group of user to react in proper way. For example, in the case of a building fire event, if the warning system observes damages of the building and generates messages which hold the clear evacuation plan, the users can immediately react to the disaster without any hesitation.

The output of analysis component is the list of relevant users and the proper messages for each of them. The notification component uses this output as an input, and disseminates the messages to the target users. At the time of the disaster event, some part of the network may be broken or end user host may not be reachable [8]. That is, unexpected failures happen in large scale, as well as in geography correlated manner. The goal of the notification component is how to keep the network more resilient to the unexpected geo-correlated large scale network failures. The action of notification component is considered as feedback and react of users.

In this paper, we propose a new design of a disaster warning system architecture which is mainly focus on considering personalized message generation (Analysis) and geo-correlated failure resilient message dissemination (Notification). The architecture of the proposed reliable and personalized disaster warning system has three main modules; personality aware location prediction module, geo-social connectivity aware message generation module, and failure-resilient geo-aware dissemination module. The personality aware location prediction module filters out targeted users who may be affected by the event, even though the users are not interesting in the event location. The geo-social connectivity aware message generation module generates messages for each set of users in order to provide personalized information of events to each individual user, as well as to maximize the coverage of message propagation through multi-modal communication channels on social connections. The failure-resilient geo-aware dissemination module manages the connectivity to users such as an overlay network of warning notification clients and supports the dissemination protocols which are highly resilient to unexpected geo-correlated severe failures caused by disaster events.

The rest of paper is organized as follows. In Section 2, the main idea of each module of the proposed system is described in detail. Also, the results of preliminary evaluations for each module are presented with the discussion of the viability of the proposed modules and system. Finally, Section 3 provides the conclusion of this paper.

II. DESIGN OF A RELIABLE AND PERSONALIZED WARNING SYSTEM

In this section, we describe each module of the proposed disaster warning system in detail. Figure 2 illustrates the overall architecture of the proposed disaster warning system. The observation, the user interface module and the database module are related to sensing component of a disaster warning system. The personality aware location prediction module and the geo-social connectivity aware message generation module are related to the analysis component of a disaster warning system. Finally, the failure-resilient geo-aware dissemination module is related to the dissemination component of a disaster warning system.

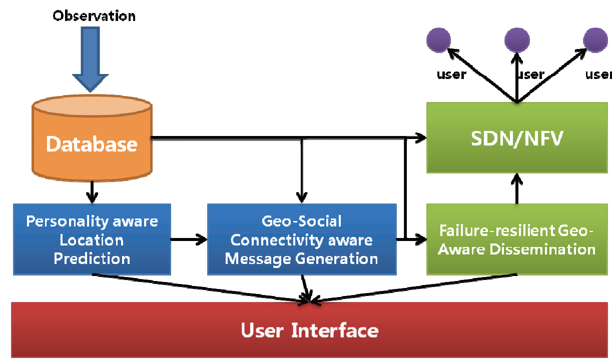

Figure 2. The architecture of the proposed disaster warnding system

A. *Observation, Database and User Interface*

The proposed disaster warning system manages interesting locations and social connectivity of users, as well as geography and other environmental information related to disaster events. To manage user information such as location subscriptions and social connectivity, a disaster warning system needs an interactive user interface. Recently we implemented a web-based interactive user interface for gathering and managing user information, as well as event information [3]. Beside the user information, other environmental information, such as geography and sensor readings can be gathered by using any IoT(Internet of Things)-based sensor network techniques [1][2] and using open API (Application Programming Interface) to other disaster portals such as USGS (United State Geological Survey). The gathered information is archived into the database module for further uses such as generating warning messages for target users.

B. *Personality-aware Location Prediction*

In the disaster warning system, the subscriptions of users are basically event type and interesting location, because a disaster event is highly coupled with geography. Also, the current location of a user and some locations where the user most likely visits are natural interesting locations of the user. To get the current location of a user, the system can gather the location of a user periodically by contacting warning notification clients which are running on machines of users.

With these user subscriptions and interesting locations, the disaster warning system filters out the relevant users to a disaster event. This process can be easily done by conducting a series of database queries. But, there is room for improvement of the filtering process. That is, even though the user does not have any subscription related to the event, the system can predict the relevant users to an event and improve the utility of the warning system. This prediction of interesting location of a user can be done by applying various machine learning techniques to user location history [4].

 ISBN: 978-1-61208-418-3

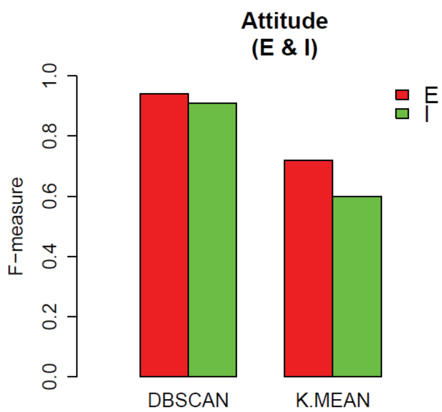

Figure 3. Performance of predicting user attitute (E: Extraverstion and I: Introversion) in MBTI (Myer-Briggs Type Indicator). SVM (Support Vector Machine) is used as a classifier and each location clustering technique is used to extract classification features.

As a novel feature of prediction of interesting locations of a user, we considered the personality of a user and its relationship to the movement pattern of the user. Recently, we researched on the relationship between user personality and their movement patterns, and we found the possibility of estimating user behavior based on the location clustering [5]. Figure 3 shows the performance of predicting user attitude personality of MBTI (Myer-Briggs Type Indicator) with different location clustering methods such as DBSCAN (Density-Based Spatial Clustering of Applications with Noise) and K-means clustering. With DBSCAN, we achieved over 90% of F-measure which is the harmonic mean of precision and recall of prediction.

As results, we found that a user with outgoing personality travels more distance and visits more places. With this finding, the personality aware location prediction module leverages the personality information to improve the effectiveness of location prediction based on user location histories.

C. Geo-Social Connectivity-aware Message Generation

A warning under a disaster event requires not only sending a message to users in the event area but also letting people close to the users informed. In an ideal case, users of the warning system immediately get a message and try to evacuate from the disaster area. But, in real cases, users may not be able to check the message, or may not be able to evacuate within time limit. For example, let us imagine that a building is on fire and fire alarms start to ring. But there may be some disabled people, old people who cannot react fast, or young children who may not react properly. In this case, it is better to let others, who are physically close to them or who are family members of those improperly reacting users in the disaster area, and let them know about their detail condition. Then, informed people can help or let someone nearby help the users.

In this case, we should consider that the message for the target users inside the disaster region is different to the message for the other users who may help them. That is, message generation module should refer the user information with its current location, as well as the social connectivity in order to make proper warning messages for different type of users.

Additionally, we can imagine the information of warning messages spread out through social connections. For example, the well made personalized warning message also increases the possibility that the recipient carefully reads the message, and it improves the coverage of message propagation.

When the message propagation is considered, we can consider the multi-modal channels for the message propagation, because users usually use various channels to propagate messages through social connections [6]. In an emergency situation, the message propagation may enhance the possibility that a message reaches to the target user within a given time limit.

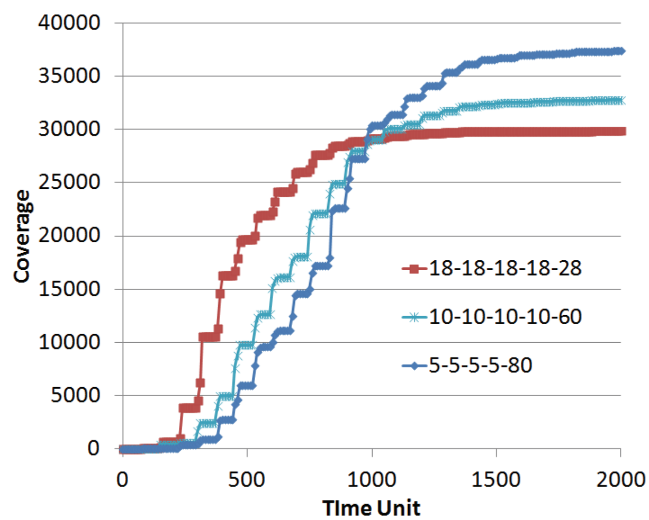

Figure 4. Propagation process with different channel preferences

Recently, we have researched on the relationship between channel preferences and the coverage of message propagation. To evaluate the relationship, the users are grouped in different five groups, and each group has different channel preferences. Figure 4 shows the coverage and the speed of message propagation under different distribution of user groups. In this figure, the portion of the fifth group, whose members prefer long delayed channel such as phone call, varies. As the portion of the fifth group increases, the speed of early stage of propagation becomes slow, but the eventual coverage of message propagation increases. That is, it is shown that the different channel preferences affect the eventual coverage of the message propagation and the speed of the propagation.

According to these consideration of message generation and propagation, the geo-social connectivity aware message generation module leverages location of users, social-connectivity of users, the multi-modal channel preferences, and possible time limits in order to maximize the performance of message propagation and the utility of a message.

D. Failure-Resilient Geo-aware Dissemination

In a disaster warning system, quickly and reliably sending warning messages to all of relevant users is the upmost important job. The users who are in the range of a disaster usually have to make a quick decision under the lack of information. For example, a man who is inside a building on fire need to quickly chooses an exit. A wrong choice at this time can be irredeemable. Therefore, giving them quick information to help them making decision is very important.

In a disaster event, there is a high probability that the network devices are ruined. In this situation, how to provide a reliable sending method is also important. For example, a mobile phone is a reliable method to send the message to user in the normal case. But in a disaster, the mobile phone can be ruined or the user cannot get the message. In this case, we need to choose another way to send the message to the user. Also, it is possible that the network devices such as switches or routers are destroyed. To send message to the user, we might have to reroute the message to another router.

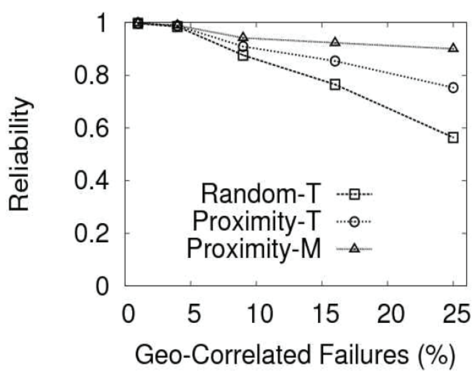

Figure 5. Reliability of message dissemination under large failures

Recently, 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. Figure 5 shows the reliability of message dissemination under various scales of geo-correlated failures with different overlay networks. The reliability is measured by calculating the rate of successful message delivery to the total number of message receivers. The “Random-T” means the random multiple tree overlays and the “Proximity-M” and the “Proximity-T” mean the mesh network and tree network with proximity aware technique to mitigate the impact of geo-correlated large scale failure [8]. As a result, the proximity aware technique improves reliability of message dissemination substantially. However, this proximity aware technique requires the router information and it is hard to realize in the current internet.

In these days, SDN (Software Defined Networking) is promised as future of internet. SDN provides centralized network management, and SDN controller can provide detail information of underlay routers and make decision based on the global view of the current network condition. With help of the SDN technology, the failure-resilient geo-aware dissemination module manages a highly reliable overlay network, which quickly and reliably disseminates a warning message to all the target users. To do that, we need a system that can analyze the network condition and adapt the sending method based on the network condition.

III. Conclusion and Future Works

The main goal of a disaster warning system is preventing loss of life or properties by providing detail information to all relevant users to a disaster event in timely manner. To achieve this ideal disaster warning system, we propose a new architecture of a disaster warning system with three important components: personality aware location prediction, geo-social connectivity aware message generation, and failure-resilient geo-aware dissemination.

Currently, we have primitive versions of each module with convincible initial findings. The natural future work is improving all the modules and combining them properly. After we build a complete system, we expand this system by applying big data sensing and analyzing techniques.

Acknowledgements

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014R1A1A1007734).

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