科技部補助

大專學生參與專題研究計畫研究成果報告

* ********* ** *
* 計　畫　　　　　　　　　　　　　　　　　　　　　　　　 *
* 　　　：重大災難緊急通訊系統設計與實作　　　　　　　　　 *
* 名　稱　　　　　　　　　　　　　　　　　　　　　　　　 *
* ********* ** *

執行計畫學生：林均彥
學生計畫編號：NSC 102-2815-C-224-004-E
研 究 期 間 ：102 年 07 月 01 日至 103 年 02 月 28 日止，計 8 個月
指 導 教 授 ：朱宗賢

處理方式：本計畫涉及專利或其他智慧財產權，2 年後可公開查詢

執 行 單 位：國立雲林科技大學資訊工程系暨研究所

中華民國 103 年 03 月 06 日

Active Disaster Response System for Smart Building

(The paper has been selected by IS3C 2014 for recommendation to *Sensor Journal*)

Chun-Yen Lin (專題生), Edward T.-H Chu (指導老師)
Department of Computer Science
Yuntech University
Douliu, Taiwan
{u9917010, edwardchu}@yuntech.edu.tw

Lun-Wei Ku, Jane W. S. Liu
Institute of Information Science
Academia Sinica
Taipei, Taiwan
{lwku, janeliu}@iis.sinica.edu.tw

***Abstract*—In recent years, major natural disasters have made it more challenging for people to protect human lives. Examples include the 2011 Japan Tohoku earthquake and Typhoon Morakot in 2009 in Taiwan. However, modern disaster warning systems cannot automatically respond efficiently and effectively to disasters. As a result, it is necessary to develop an automatic response system to prevent, diminish or eliminate the damages caused by disasters. In this paper, we develop an active disaster response system (ADRS) to automatically process standard warning messages, such as common alerting protocol (CAP) messages. After receiving official warning messages of earthquakes, ADRS automatically shuts down natural gas lines in order to prevent buildings from fire and opens the building doors for easy evacuation. In addition, the ADRS automatically forms an emergency network for trapped victims to report emergency. The ADRS system can be applied to hospitals to tell surgeons to pause on-going operations, or to supermarkets to inform consumers of the way to exit the building. According to our experiment results, the proposed system can avoid possible dangers and save human lives during major disasters.**

***Keywords*—Intelligent System, Disaster Preparedness, Smart Environment, Automatic Response System**

I. INTRODUCTION

Emergency disaster systems are ubiquitously utilized in our lives like schools, homes, buildings, etc. They help the public to be aware of emergency information so that they can protect themselves safety to reduce hazard damage before disaster strike. Recently, there have been many countries that have suffered major disasters, e.g. the 2009 Taiwan Morakot typhoon, the 2010 Haiti earthquake, and the 2011 Japan Tohoku earthquake. All of these disasters caused serious damage in those countries. Although people can get warning messages published by the Central Weather Bureau via television, SMS, radio, and social network in advance to protect themselves safely, we found that disasters like earthquakes are hard to prepare for and that the damage happens quickly. These kinds of emergencies require a very fast response time to reduce damage efficiently so that many people are not trapped inside their houses or buildings. Therefore, how to have more time for evacuation and preparedness in order to reduce damage is an important issue in most countries.

Many systems have been developed for disaster response. One uses the Geographic Information System (GIS) [1] to analyze historical information of disasters and geographic environments, and it provides potential details of the places where disasters are most likely to strike. Another uses Twitter tweets to send warning messages [2][3], this happens when other Twitter users feel an earthquake. Volunteers post tweets about the earthquake. After the system receives these tweets, it classifies them by using Kalman or Particle filtering to get more disaster details. Finally, it uses e-mails to notify users. The other method is to use sensors to monitor building situations [4]. When sensors sense unexpected incidents or events, they will automatically control home devices to protect households. In this way, the disaster response time is shortened to help people avoid danger and be safer. However, all these works cannot provide enough time for preparedness and evocation. They also cannot collect sufficient messages from affected areas to help relief workers rescue victims.

In order to have enough time to take a proper response when an earthquake happens and collect sufficient messages from affected areas, we developed a system which we call the Active Disaster Response System (ADRS), to automatically perform corresponding work as quickly as possible that people can have more time to find safety and escape danger. This can also reduce the number of people affected by these disasters and the loss of property. After a disaster, the ADRS also collects information of affected areas in order to speed up relief operations. In our implementation, we adopted the Tibbo EM1000TEV microcontroller development kit to receive emergency warning messages from the Central Weather Bureau, and parse these messages to extract all data about the disasters. Accordingly, ADRS can control devices to do corresponding disaster work, and provide information on family members' positions automatically. The ADRS integrates members' messages and delivers them to rescue centers to help collect information. According to our experiment results, the proposed system can avoid possible dangers and save human lives during major disasters.

II. RELATED WORKS

Disaster Management is an attempt to reduce natural disaster damage. It consists of four stages, which are mitigation, preparedness, response, and recovery. In this paper, we focus on the preparedness and response stage. We address the issue of getting faster reaction time during disasters as well as after disasters.

A. Disaster Warning System

L. Wijesinghe *et al*. [5] proposed a GSM-based system to build a Disaster Early Warning network. It delivered warning messages via SMS and CBM. When the system receives messages, it will make noises, flashlights, and broadcast to notify people. But this method cannot provide enough time for people to always escape safely from disasters, especially earthquaks since they frequently happen with little warning. K.M. Rahman *et al*. [6] proposed an OpenStreetMap (OSM) to provide geographic information. Before a disaster strikes, it used C2DM to notify people about warning information and calculated the shortest path so as to help people escape to safe areas. This method cannot collect information in affected areas and cannot guide volunteers to help people that are trapped. Jinhee Park *et al*. [7] proposed a heterogeneous warning system that uses different a warning system to share information. Their system helps people get warning messages rapidly to escape or evacuate from dangerous areas, but the system still cannot provide enough reaction time or collect sufficient information to efficiently reduce disaster damages. R. Azmi *et al*. [8] proposed the DVB method to broadcast disaster warning messages via digital television. But in the limited response time, people do not have time to escape or evacuate and there is a higher probability that people will still be trapped indoors. N. Adam *et al*. [9] proposed social media to collect disaster information via blogs, Twitter, etc. They broadcast warning messages through smart phone, MMS messages, television, satellite, etc. to let people get messages. However this method cannot achieve a faster reaction time during disasters and cannot reduce disaster damage efficiently. The above research shows that people often know disaster information in advance, but often do not have enough time to find a safe place to avoid danger. In this work, we focus on getting more reaction time to reduce damage efficiently.

B. Disaster Surveillance System

In order to grasp disaster information promptly, some researches efforts have been denoted to develop disaster surveillance system. Gerardo Di Martino *et al*. [10] proposed Synthetic Aperture Radar (SAR) that adopted radar monitoring geographic information. They make a decision based on the image information. But, this method can only get information roughly. Linlin Lu *et al*. [11] proposed Virtual Human Resources (VHR) to picture ground information and evaluate the collapse of buildings. However, their system didn't know the number of people trapped indoors details and their SOS messages. J. Post *et al*. [12] proposed Earth Observation and modeling technologies to monitor disaster damage. But this method only knows information of the damage area like landslide or flooding, it cannot collect affected people information. Michael Muller *et al*. [13] propose by globally distributed rescue units shared to monitor disaster, and collect information that can speed-up relief operations. This method can't get people in danger information that cannot know people situation to rescue them rapidly. All above methods cannot provide geographic information about the people who are really trapped indoors. In this works, we adopt embedded boards in buildings to collect threatened areas information so that we can help official agencies rescue actions.

C. Disaster Information Collection

Some crowdsourcing strategies are applied in collecting information, and these are combined with the Web 2.0 social network. Adriana S. Vivacqua *et al*. [14] proposed the crowdsourcing strategy to collect information like Wikipedia. This strategy claims we can save important information these crowd sources. We classify our required information by saving data that speeds up relief operations. Jie Yin *et al*. [15][16] proposed social media as a way to quickly gather information about disaster situations from people close to these disasters or trapped in them which had been instantly made public, e.g. SOS messages or disaster impact pictures to help governments monitor disasters and decide which supplies or personnel to send or assign. Weifeng Shan *et al*. [17] and Shim Hyoung Seop *et al*. [18] proposed collecting information using smart phones. People would upload pictures, videos, text messages and these would be forwarded to the server database. Rescue centers obtain disaster information this information about trapped people's needs through this database. J. Farber *et al*. [19] proposed the Riskr project that builds disaster portals to collect disaster messages via the Web 2.0 social network from Twitter. It helps rescue centers so they can better grasp the damage from any large-scale disaster rapidly. The above research shows that the crowdsourcing strategy is feasible for executing rescue attempts; but that it does not integrate an effective pre-disaster prevent system. Our ADRS can automatically do disaster relief and management to help people escape or evacuate, dangerous situations, as well as automatically providing information about household members' situations.

All the above mentioned methods are not able to perform automation disaster works. In addition, they are not able to collect information about threatened areas. On the contrary, our ADRS helps speeds up the response time during disasters aiding people to escape danger or find safe refuge. It also is combined with smart phones to quickly notify individuals and help rescue centers to quickly gather information and act quickly on that information.

III. Problem Statement and Challenges

A. Problem Statement

Emergency disaster systems are applied in disaster responses ubiquitously. Pre-disaster preparations, however, can increase public safety and reduce hazard damage. Our research problem was to find a way in increase the speed of disaster responses, and how to quickly gather data about disasters from the affected areas. Our overall goals were to develop a system that provides a fast response to disasters and aids volunteer rescue and relief efforts. For this, we designed ADRS to help the public have faster and more timely information to escape or be evacuated from disaster areas.

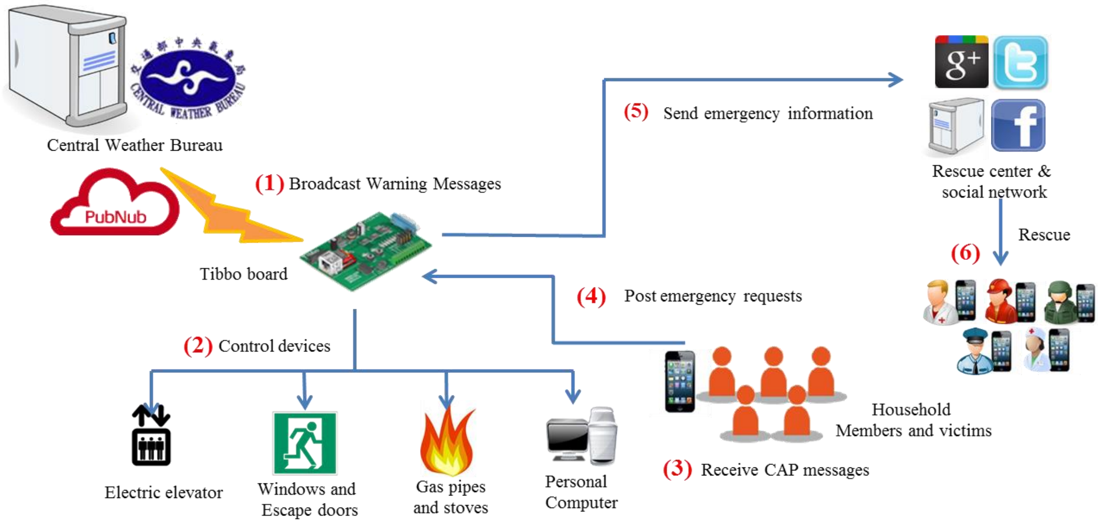

Fig. 1 Active disaster response system flow chart

After a disaster has struck, we can rapidly get information from those areas to speed up relief operations and minimize damage.

B. Difficulty and Challenges

There are two major challenges to design a disaster response system. First, when a disaster happens, how to decrease the time it takes to assist the public to find safety before, during or after a disaster. The state of the art in this field is to notify people via television, SMS, radio, social network, etc. The public gets these warning messages as early as possible to protect themselves. The above methods perform well for most disasters, but it may not be suitable for earthquakes. Thus, for earthquakes, we developed ADRS to automatically perform corresponding disaster management to assist the public to quickly escape danger or be evacuated from dangers.

The second challenge we faced was how to collect the necessary information quickly after a disaster had struck, especially during the golden 72 hours. The common surveillance system is to use satellites or planes to explore threatened areas, and process image information for further use. However, these images may not provide enough information, especially at night or during bad weather. For this, we collect information from embedded boards in building and provide the collected information to official responders.

IV. Active Disaster Response system (ADRS)

In this section, we desribe ADRS in details. When disaster happens, ADRS first gets warning disaster messages sent by official agencies, and extracts disaster messages followed by CAP international standard format. According to disaster information, ADRS will automatically control householde device for doing corresponding prevention works to protect people safe. If disaster caused network broken, we build up emergency message board which is embedded into Tibbo device to help people trapped inside house have communication capability. The rest of sections arrange as overview, emergency broadcast system, and active disaster response system.

A. Overview of ADRS

In order quicken the time it takes to respond to a disaster, our system is illustrated as shown in Fig. 1. When the Central Weather Bureau (CWB) publishes warning messages, we get information about disasters via smart phones (Step 1). Tibbo in homes also receive warning messages through that network (Step1), and parses XML-based messages to extract disaster information. According to the disaster information, our system controls household devices like opening doors, cutting off power and gas, and other functions (Step 2). For example, we would open escape doors and cut off the gas to prevent possibly injury to household members and to allow them to evacuate more quickly. After receiving warning messages, household members can report their information to Tibbo (Step 3 and Step 4). Tibbo will deliver these messages to rescue centers to help volunteers efficiently execute rescue efforts (Step 5). After rescue centers gather this disaster information and integrate with different sources messages, they will arrange relief workers to rescue victims and provide supplies requirements (Step 6). In this way, the public have more time to escape or evacuate, and victims have more chances to be rescued that can prevent, diminish or eliminate the damages caused by disasters.

B. Emergency Broadcast System

We design an emergency broadcast system to simulate the Central Weather Bureau to publish warning messages. We adopt PubNub's real-time push service [20] to push warning messages to specific devices. As Figure 2 shows, PubNub provides a real-time push service in the cloud. It can deliver hundreds of thousands, even millions of messages to each device. Our emergency broadcast system publishes XML-based Common Alerting Protocol messages to Tibbo [21] and smart phones by PubNub. With these warning messages, people can get disaster information early and have more time to escape. In our implemented, we used a smart phone as emergency broadcast system to publish disaster warning messages.

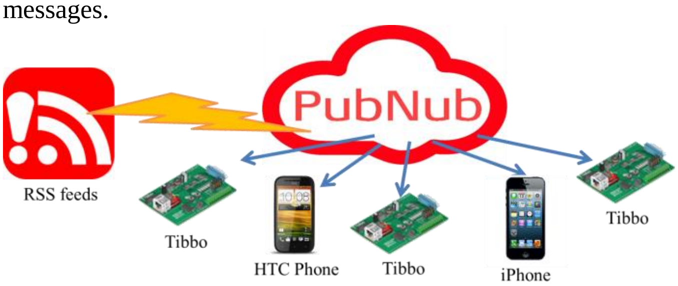

Fig. 2 Deliver messages via PubNub

For this, we first registered a PubNub account to get our own subscribe key, publish key, and secret key. We then use the publish key and subscribe key to publish and retrieve warning messages, as Table 1 lists.

Table 1. PubNub APIs used in ADRS [20]

API name	Description
Pubnub	To create pubnub service, puts parameters as publish_key and subscribe_key
Publish	To publish messages, puts parameters as channel_name, messages
Subscribe	To subscribe messages, puts parameters as channel_name, Callback function

In our implementation, we got Pubnub-Android-3.5.6.jar and bcprov-jdk15on-1.47.jar from PubBub official website. These two files are used to execute PubNub services. Figure 3 shows user interface of emergency broadcast system on an Android smart phone. It provides key functions to publish warning message, such as publish, subscribe and so on. Figure 4 shows a warning message of earthquake received by end user. The messages delivered by PubNub help users become aware of disaster situation.

Fig. 3 PubNub Broadcast

Fig. 4 PubNub Receiver

C. Active Disaster Response System

The active disaster responses consists of three key components: CAP message parser, emergency message board and emergency report system. We desribe each of them as follows.

1) CAP Message Parser: As shown in Fig. 5, we registered for the CAP messages provided by the Emergency Warning Service (EWS), e.g. Emergency Digital Information Service (EDIS), National Science and Technology Center for Disaster Reduction (NCDR) [23], Integrated Public Alert and Warning System (IPAWS). There are two ways to get warning messages. One is from RSS feeds and the other is from E-mail. After registering for the CAP services, XML-based format messages will be sent by E-mail or RSS.

Fig. 5 CAP messages published by EWS

We follow the Common Alerting Protocol (CAP) [22] standard to interpret warning messages. As Figure 6 shows, a CAP message contains four parts. They are alert, info, resource, and area. After receiving the warning message published by official agencies, our CAP parser extracts important messages. In the part of Alert, we extract the message of Message ID, Sender ID, Sent Data and so on. In the part of Info, we extract Event Category, Event Type, Urgency, Severity and so on. In the part of Resource, we extract Description. In the part of Area, we extract Area Description. Common Alerting Protocol Validator (CAPV) [24] to validate the correctness of our parser.

Figure 7 shows the flow of parsing CAP message and control devices. After parsing CAP messages, we obtain earthquake information like urgency, severity, magnitude, depth, etc. Based on the extracted information, the active disaster response system automatically controls devices to avoid possible dangers. For example, it can open escape doors or entrances, stop the elevator nearby, cut off the gas, and cut off electronic devices so that the public has more time to respond to disasters and find safety.

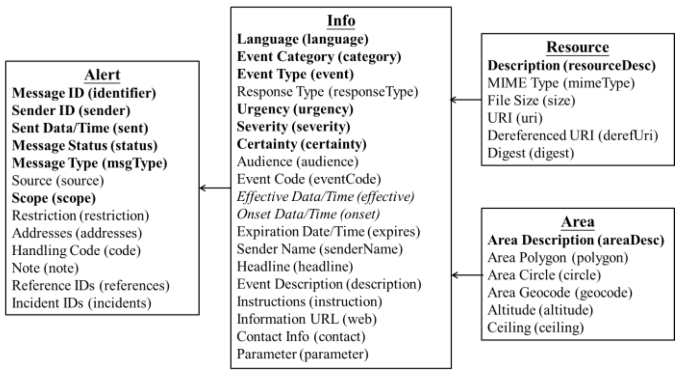

Fig. 6 Common Alerting Protocol Architecture

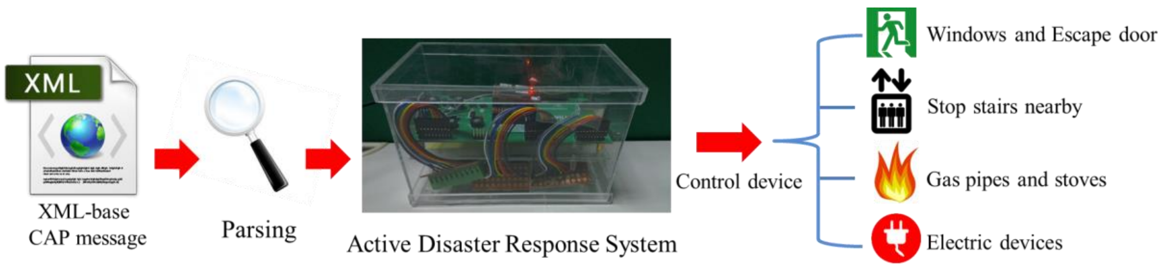

Fig. 7 The flow of parsing CAP message and control devices

2) Emergency Message Board: When major disaster happens, it may broken the network connectivity. As a result, victims in the threaned area may not be able to post emergeny. In order to address this problem, we designed a temprary network by utilizing the embedded boards in buildings. In this work, we use Tibbo EM1000-TEV embedded board to build up a prototype.

Table 2. Active Emergency Disaster System Specification

Tibbo EM1000-TEV Specification	
1.	88 MHz RISC chip (T1000)
2.	10/100 BaseT auto-MDIX ethernet
3.	Provide Wi-Fi interface (GA1000 module)
4.	Four high speed serial port (CMOS)
5.	1024KB flash memory for fireware, and application
6.	2KB EEPROM for parameters, and data store

Table 2 shows the hardwarde specifiction of Tibbo EM1000-TEV device specification. The core of the board is a RISC chip with 88 Mhz. In particular, it supports both Wi-Fi and ethernet interface. It also has a 2KB EEPROM to store important informaiton.

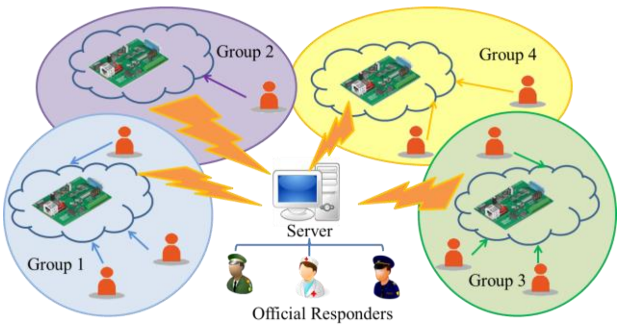

Fig. 8 Usage Scenario of Emergency Message Board

Figure 8 shows the usage scenario of emergency board. There are several embedded boards in buildings. Each of them have network capacity. When internet is disconnected, people can connect to these embedded boards directly and post emergency events. The events are stored in embedded boards. As Figure 8 shows, people or victims are divided into several groups, depending on their locations. When offical responders arrive the threathened area, they can get emergency reports from these embedded boards. Since embedded boards are usually powered by battery, it is necessary to reduce possible communication to save energy. As a result, for people or victims, it is necessary to properly select a embedded board to store their emergency message.

Figure 9 shows the UI interface of our emergency message board. Victims can use the interface to post emergency messages on embedded boards.

Fig. 9 Emergency Message Board Interface

In order to address this issue, we design a heurisitic algorithm to select an embedded board to store emergency messages. For each victim i, we use m_i to denote the size of emergecny message needed to be posted to an embedded board Tibbo. Also, e_i is the approximated energy consumption of receving the emergency message. At beginning, the victim will search embedded boards near by and query the remaining energcy capacity and memory capacity of each mebedded board. We assume that the number of Tibbo near by victim i is k. The remaining energy capacity of the kth Tibbo is E_k and its remaining memory capacity is M_k.

As shown in Algorithm 1, we adopt post function to select a suitable Tiboo board to post the emergency message. Our goal is to reduce energy consumption as much as possible when posting emergency messages. For this, we examin all Tiboo boards near by the victim i (line 3 to 9). If the remainig energy capacity of the Tiboo board is larger than e_i and its remaining memory capacity is larger than, it will be selected as a candidate. We pick up the embedded board among candidates with the highest energy as the result (line 5 and 7). After selecting the target embedded board, we post emergency message to the board. The advantage of our method is easy of implementation and can be intergrated with emergency exit light equipment. When official responders arrive the threanted area, they can conntect to these embedded boards to obtain emergency requests.

Table 3. Post emergency messages

Algorithm 1 Post emergency messages
Input: m_i , e_i , k, E_k, M_k,
m_i : the size of emergecny message needed to be posted
e_i : the approximated energy consumption of receving the emergency message.
k : the number of Tibbo near by victim i is k.
E_k : the remaining energy capacity of the k^{th} Tibbo
M_k.:the remaining memory capacity of the k^{th} Tibbo
S: The selected Tibbo board

```
Procedure Post
S = Null;
for j = 1 to k do
   if S==Null & E_j > e_i & M_j > m_i then
      S = j;
   else if S!=Null & E_j > E_s & M_j > m_i then
      S = j;
   end if
end for
if S is not Null
   Connect to Tibbo board S;
   Post the emergency message on S;
end if
```

3) Emergency Report System: The purpose of our emergency report system is to send collected disaster information to official agency for further use. Figure 10 shows how ADRS reports emergency evnets to our previsou work Ushahidi[+][26], which is a crowdsourcing-enhanced emergency management system. As Figure 10 shows, when disaster happens, the disaster information is first collected by official responders, ADRS, witness or victims (Step 1). The responsibility of ADRS is to collect victims' information through sensors deployed in buildings and report the emergency to Ushahidi+. The collected disaster information is store in the database of Ushahidi+ for threat level or threatened areas analysis (Step2). The original Ushahidi classified events into eight types: emergency, vital lines, public health, security threats, infrastructure damage, natural hazard, services available and others. In our implementation, system administration should assign a score to each type of event to indicate its emergency level. If the threat level or threatened areas is not affordable, the official agency will post volunteer recruitment messages on social network, such as Facebook or Twitter, in order to attract more volunteers to improve rescue actions (Step3). People who want to volunteer on rescue actions can report their personal information, such as name, location and professional speciality, to the official agency by our emergency APP or Ushahidi+ web interface. After recruiting enough volunteers, the official agency then triggers participant selection process in order to supplement surveillance sensor coverage (Step 4). The allocation results are sent to volunteers (Step 5). Different volunteers may be assigned to different region to collect different disaster information. After volunteers arrive the target region, our path planner [20] then calculates a precise route to the destination for each volunteer (Step 6). Finally, all information collected by the volunteers is sent back to the official agency for further analysis. Readers who are interested in Ushahidi[+], please refer to our previous work [25][26].

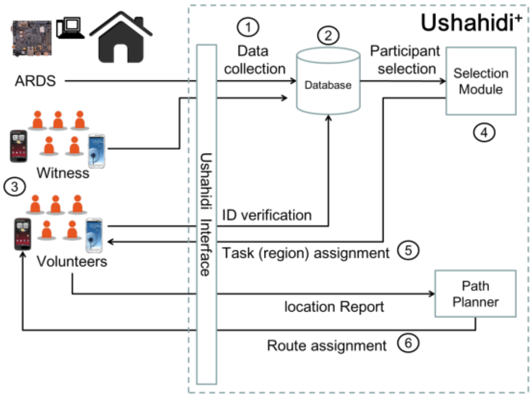

Fig. 10 The relationship between ADRS and a crowdsourcing-enhanced emergency management system

V. EXPERIMENT RESULTS

We now are going to introduce the ADRS. It consists of three parts of the Tibbo development kit. They are the input/output control lines, and the Wi-Fi SPI module. First, we use Tibbo to receive warning messages published by the Central Weather Bureau, and parse the XML-based format CAP messages to extract disaster information. Second, we adopt the Wi-Fi SPI module that provides Tibbo have with its wireless network function. Tibbo can also collect household members' messages with the wireless network. These messages are saved in the flash memory of the web server. The last part of our system is the input/output control lines. These controls lines can control relay switches so that home devices can be turned on or off and opened or closed.

A. Trial Field

Fig. 11 shows our evaluation environment, in which Tibbo EM1000TEV's input/output controls the lines to connect to the fuse breakers and other household devices. Household devices are controlled by ADRS, such they can be opened or close in order to protect residents at home. In addition, Tibbo can control alerts, doors, power, gas, etc. or even use Wi-Fi wireless networks to control devices like personal computers to save important data. Our system can be applied to many types of buildings or institutions in order to better protect the public from many hazard related to disasters, both inside and outside the home. We installed ADRS at EB208 smart home environment's class room in National Yunlin University of Science and Technology to do the experiments. The result of experiments showed our system really can provide residents more response time to escape or evacuate. It has dramatically improvement for people having more help chances when disaster struck.

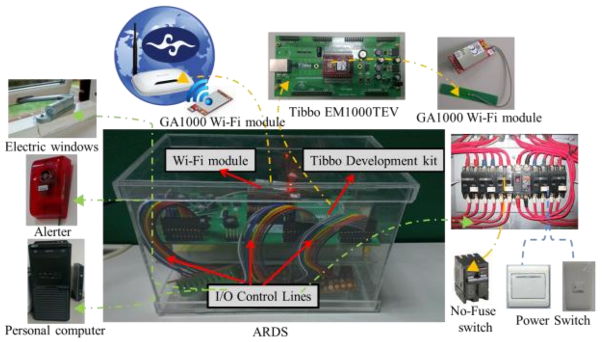

Fig. 11 Setup of trial field environment

For example, when the ADRS receives warning messages, it will automatically shut down personal computers to save important data. As shown in Figure 12, by using the PubNub service to broadcast earthquake warning messages, Tibbo and smart phones can receive disaster information. As shown in Figure 13, after receiving the CAP messages, the ADRS extracts warning disaster messages, and shows the associated earthquake information to do corresponding prevent works.

Fig. 12 CAP message

Fig. 13 Warning information

B. Estimation of Disaster Response Time

Fig. 14 shows the time to perform each task when a disaster happens. The tasks include opening doors, cutting off gas, shutting down computers and so on. From Fig. 14, we know that all of the actions take 16.56 seconds. Residents are hard for performing all of the actions when disaster struck so that many people cannot complete these prevention works in time and cannot escape or evacuate successfully. Because of less response time, it makes severity damage that lots of citizens are trapped inside house, even dead when major disaster strikes.

Our ADRS goal is that the public can have more response time escape with the support of the ADRS. With ADRS automatically control household devices to help people avoid potential dangers, and have more chances escape to be safe.

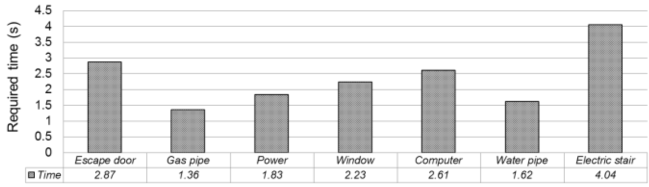

Fig. 14 Time to perform each task

As shown in Fig. 15, the figure illustrates the floor plan of the Engineering Building V in National Yunlin University of Science and Technology. Totally, the building has six doors for exiting the building, and the classrooms and offices have windows. There is an elevator that services all floors. To manually perform each task when a disaster happens is difficult because opening doors takes 2.87 seconds, opening the windows requires 2.23 seconds, stopping stair nearby needs 4.04 seconds, and shutting down computers needs 2.61 seconds. It requires a total of 11.75 seconds to do all of earthquake tasks. With the support of ADRS, we can do these tasks automatically after an earthquake happens. As a result, students and faculties can have more time to escape or evacuate and losses from damages are reduced.

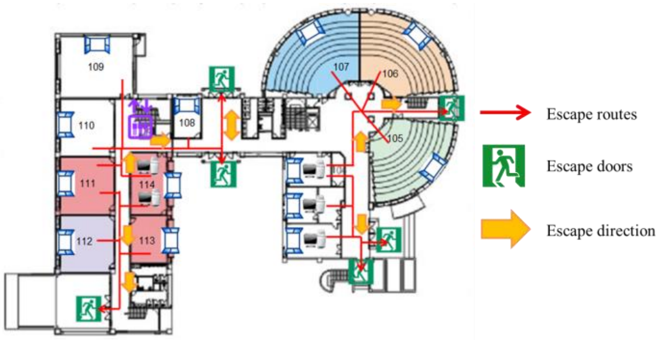

Fig. 15 Floor plan for evacuation

C. Effect on Evacuation Time

Fig. 16 shows the effect of the ADRS on evacuation times. We adopted the floor plan of the Engineering Building V in National Yunlin University of Science and Technology to estimate the time for evacuation if students are on the first floor, second floor, third floor, and fourth floor respectively. We compared the evacuation times both with and without ADRS.

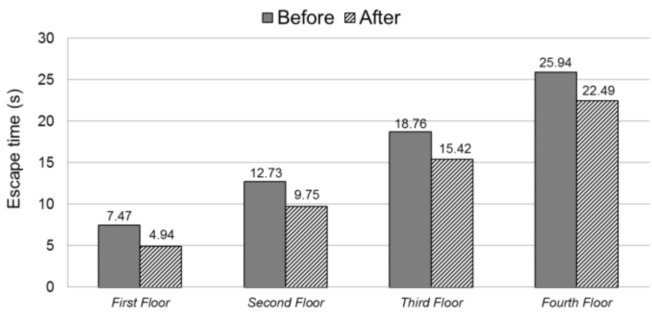

Fig. 16 Comparison of evacuation time

Our experiments show that the ADRS can reduce evacuation times by twenty percent time. The experimental data include only the time to open the doors. The more tasks that can be performed automatically, then, the more time there will be available to safely evacuate the building.

D. Stability on Emergency Message Board

In order to test the stability of our emergency boards, we conducted a star network for experiment. We use web interface to upload emergency messages from smartphones. Each smart phone connects to the embedded board in one hop. The size of a message is 20 bytes which represents a short emergency in real scenario. We study the effect of in number of connection on stability. In this experiment, we use the success rate of packet transmission as performance index. For each connection, we repeat the translation 100 times and take the average as the result. As Figure 17 shows, our emergency message board maintains a very high success rate in packet transmission. When the number of connection increases to 4, the success rate slightly decreases to 94.64%. The experiment results show that ADRS can be applied to real scenarios for practical use.

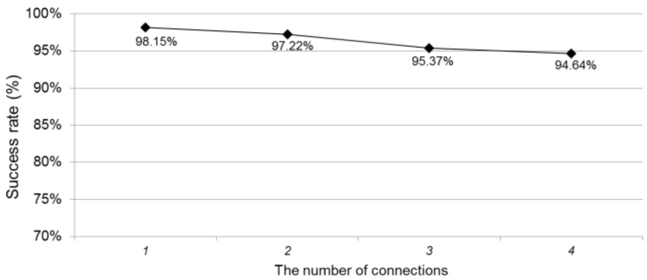

Fig. 17 Stability of Emergency Message Board

VI. CONCLUSIONS

In this paper, we proposed the ADRS to automatically receive warning messages sent from official agencies, such as the Central Weather Bureau, and parse warning messages to obtain disaster details. According to disaster information, the ADRS automatically performs tasks and collects victims' information through Tibbo. The collected information is then sent back to rescue centers. We expect that, in the near future, most buildings will install ADRS-like systems so as to protect human lives during major disasters. According to our experiment results, with the support of the ADRS, the public will have more time for evacuation and damages from disasters will be reduced. In the future, we plan to install the ADRS in different environments to collect more real data, such as in a shopping mall. We also plan to construct an emergency network to transmit collected information to official rescue centers.

ACKNOWLEDGMENT

The work was supported by National Science Council, Taiwan Project NSC 102-2219-E002-022, NSC 101-2815-C-224-040-E, NSC 102-2815-C-224-004-E and Academia Sinica Project AS-101-TP2-A01.

REFERENCES

[1] Cao Zhenyu, Zhu Jun, and Gan Rongcheng, "Application of web 3D GIS for dam-break flood modeling," in *The First International Conference on Agro-Geoinformatics*, pp. 1-5, Aug. 2012.

[2] Takeshi Sakaki, Makoto Okazaki, and Yutaka Matsuo, "Earthquake shakes Twitter users: real-time event detection by social sensors," in *Proc. of the 19th international conference on World Wide Web*, pp. 851-860, April 2010.

[3] Takeshi Sakaki, Makoto Okazaki, and Yutaka Matsuo, "Tweet Analysis for Real-Time Event Detection and Earthquake Reporting System Development," in *IEEE Transactions on Knowledge and Data Engineering*, vol. 25, no. 4, pp. 919-931, April 2013.

[4] Hui Hong, Weikang Wu, and Kaiyuan Wang, "Design and implementation of environmental monitoring system in intelligent home," in *The IET International Communication Conference on Wireless Mobile and Computing*, pp. 522-926, Nov. 2011.

[5] L. Wijesinghe, P. Siriwardena, S. Wijeratne, H. Purasinghe, and D. Dias, "Disaster and Emergency Warning Network (DEWN): Harnessing Cellular Technologies for Early Warning Dissemination," in *IEEE Global Humanitarian Technology Conference*, pp. 476-480, Nov. 2011.

[6] K.M. Rahman, T. Alam, and M. Chowdhury, "Location based early disaster warning and evacuation system on mobile phones using OpenStreetMap," in *IEEE Conference on Open Systems*, pp. 1-6, Oct. 2012.

[7] Jinhee Park, Jinwook Chung, and Hwijin Kang, "Design of disaster alerting information disseminator," in *International Conference on New Trends in Information Science and Service Science*, pp. 86-89, Oct. 2011.

[8] R. Azmi, H. Budiarto, and R. Widyanto, "A proposed disaster emergency warning system standard through DVB-T in Indonesia," in *International Conference on Electrical Engineering and Informatics*, pp. 1-4, July 2011.

[9] N. Adam, J. Eledath, S. Mehrotra, and N. Venkatasubramanian, "Social media alert and response to threats to citizens (SMART-C)," in *IEEE International Conference on Collaborative Computing: Networking, Applications and Worksharing*, pp. 181-189, Oct. 2012.

[10] Gerardo Di Martino, Antonio Iodice, Daniele Riccio, and Giuseppe Ruello, "Use of Synthetic Aperture Radar Images for Crisis Response and Management," in *2012 IEEE on Global Humanitarian Technology Conference*, pp. 138-142, Oct. 2012.

[11] Linlin Lu, Huadong Guo, C. Corbane, Martino Pesaresi, and D. Ehrlich, "Rapid Damage Assessment of Buildings with VHR Optical Airborne Images in Yushu Earthquake," in *2012 2nd International Conference on Remote Sensing, Environment and Transportation Engineering*, pp. 1-3, June 2012.

[12] J. Post, S. Koshimura, S. Wegscheider, A. Muhari, M. Muck, G. Strunz, H. Gokon, S. Hayashi, E. Stein, and A. Ramanauskas, "Contribution of earth observation and modelling to disaster response management: Methodological developments and recent examples," in *2012 IEEE International on Geoscience and Remote Sensing Symposium*, pp. 947-949, July 2012.

[13] Michael Muller, and Sacha Chua, "Brainstorming for Japan: rapid distributed global collaboration for disaster response," in *Proc. of the 2012 ACM annual conference on Human Factors in Computing Systems*, pp. 2727-2730, May 2012.

[14] Adriana S. Vivacqua, and Marcos R. S. Borges, "Taking advantage of collective knowledge in emergency response systems," in *Journal of Network and Computer Applications*, vol. 35, no. 1, pp. 189-198, Jan. 2012.

[15] Jie Yin, A. Lampert, M. Cameron, B. Robinson and R. Power, "Using Social Media to Enhance Emergency Situation Awareness," in *IEEE Intelligent Systems*, vol. 27, no. 6, pp. 52-59, Nov. 2012.

[16] Jie Yin, Sarvnaz Karimi, Bella Robinson, and Mark Cameron, "ESA: emergency situation awareness via microbloggers," in *Proc. of the 21st ACM international conference on Information and knowledge management*, pp. 2701-2703, Oct. 2012.

[17] Weifeng Shan, Jilin Feng, Jianjun Chang, Fan Yang and Zhonghua Li, "Collecting Earthquake Disaster Area Information Using Smart Phone," in *Proc. 2012 International Conference on System Science and Engineering*, pp. 310-314, July 2012.

[18] Shim Hyoung Seop, Min Geum Young, and Jeong Duke Hoon, "A study on the development of disaster information reporting and status transmission system based on smart phone," in *International Conference on ICT Convergence*, pp. 722-726, Sept. 2011.

[19] J. Farber, T. Myers, J. Trevathan, I. Atkinson, and T. Anderson, "Riskr: A Low-Technological Web2.0 Disaster Service to Monitor and Share Information," in *The 15th International Conference on Network-Based Information Systems*, pp. 311-318, Sept. 2012.

[20] PubNub. [Online]. Available: http://www.pubnub.com/

[21] Tibbo. [Online]. Available: http://tibbo.com/

[22] Common Alerting Protocol. [Online]. Available: http://en.wikipedia.org/wiki/Common_Alerting_Protocol

[23] National Science and Technology Center for Disaster Reduction. [Online]. Available: https://alerts.ncdr.nat.gov.tw/

[24] Common Alerting Protocol Validator (Google). [Online]. Available: http://cap-validator.appspot.com/

[25] Edward T.-H Chu, C.-Y. Lin, P. H. Tsai and J. W. S. Liu,"Participant Selection for Crowdsourcing Disaster Information," In *3rd International Conference on Disaster Management and Human Health: Reducing Risk*, Improving Outcomes, Coruña, Spain, July, 2013.

[26] Edward T.-H Chu, C.-Y. Lin, P. H. Tsai and J. W. S. Liu,"Design and Implementation of Participant Selection for Crowdsourcing Disaster Information," *Journal of Safety & Security Engineering*, to appear.