A Real-time Decision Support with Cloud Computing Based Fire Evacuation System

*Liou Chu
Department of Innovative Information and Technology
Tamkang University
I-lan County, Taiwan, R.O.C.
e-mail: chuliou@mail.tku.edu.tw

Shih-Jung Wu
Department of Innovative Information and Technology
Tamkang University
I-lan County, Taiwan, R.O.C.
wushihjung@mail.tku.edu.tw

***Abstract*— An effective evacuation system can help people escape from building fire. Most evacuation systems consist of a indoor positioning system, a back-end database, and a display device with calculation and display software. However, very few of them can smartly determine which evacuation route is the best decision. If all the locations of the evacuating people can be simultaneously determined, the best evacuation routes can be decided to avoid congestion, and survival rate can increase. The previous radio frequency identification (RFID) based evacuation system focused on detecting the RFID tags using a mobile phone in order to determine the location of the mobile phone user so that an evacuation route can be displayed. However, the system is available for one person regardless of the number of evacuating people or exits. This study is based on the previous RFID based evacuation system investigating the best evacuation routes. The system introduces cloud computing that calculates for positioning the evacuating people and determining the optimum evacuation routes for each of them. The system will be implemented at Tamkang University on Lanyang campus.**

Keywords*—-fire evacuation; RFID; mobile phone; Cloud computing.

I. INTRODUCTION

When building fire takes place, one of the most common scenarios is panicking people running for the door resulting congestion. When the fire spreads rapidly with strong heat and smoke, it is extremely difficult for crowded people to escape even they have found the emergency exit. A sophisticated design of evacuation routes should be able to position all the escaping people, and determine appropriate direction to each of them.

A hybrid building fire evacuation system (HBFES) using mobile phone combined with Radio Frequency Identification (RFID) techniques has been designed [1]. This HBFES consists of a set of RFID array, several existing software namely Viewpoint Calculator, Path planner, MobiX3D viewer, and a Location Based Service (LBS) connected with the central fire alarm system. When fire takes place, the system initiates the evacuating program on the mobile phone in which a RFID reader is installed. The mobile phone reads the signals from the pre-mounted RFID tags to calculate the present location, followed by presenting a possible evacuating route. The mobile phone repeatedly executes the procedure to refresh the location and evacuation route until the user left the sensing range. All the sensing, calculating and displaying processes are accomplished in the mobile within very limited time.

Most commercialized smartphones can perform the stated functions like a portable computer. However, the performances can be very different. When executing a number of processes at the same time, it is very likely that the performance of the mobile phone becomes inadequate. In addition, the battery of the mobile phone can be exhausted very soon that might endanger the evacuation process. If an external system can take over the calculating process, the most time consuming process, the performance of the mobile phone can significantly raised to increase the success rate of evacuation.

Cloud computing is the extension of distributed computing which combines internet applications [2]. The concept is to divide user's data into multiple individuals, and then send to servers for execution. Cloud Service helps servers share the work to process numerous data. After servers finish operation, it will send calculated data back to user.

If the HBFES utilizes cloud computing as an external system performing calculation to determine the location of the mobile phone and then provide a possible evacuating route, the mobile phone can rapidly sense the RFID signals, send to the cloud service, and receive the estimated location and evacuating route to display within very short time. In addition, the system can provide calculation for all the people in the building to determine their locations simultaneously, and assign various evacuating routes to avoid congestion. The information of the fire scene can also be provided to the fire brigade.

The aim of this study is to re-design the HBFES on a smartphone connected to cloud computing. In order to compare with the previous HBFES, the same RFID temperature sensing devices are used to record the temperature and locations inside the building. The algorithm of determining the optimum evacuation routes is investigated. A computer is connected to the internet to simulate the external cloud computing service performing calculations to determine the locations of the people in the building, followed by presenting the possible evacuation routes. The system will be implemented at Tamkang University on Lanyang campus.

This paper consists of the following sections: a brief introduction is presented in section 1 followed by the related work in section 2. The system architecture is described in sections 3. Section 4 describes the algorithm of finding the optimum evacuation routes, followed by the conclusion in the last section.

II. RELATED WORK

Lim et al. [3] has presented a Human Evacuation Modeling by the discrete element method that evacuating speed is estimated provided the number of evacuating people and moving speed. The different results of two types of emergency exits show that if the dimensions of the building are input into the database, the capacity and evacuation speed can be estimated.

The positions of the evacuating people are still the key issue to an evacuation system. For example, Inoue et al. [4] developed a system applying beacon radio signals with a mobile receiver to position the escaping people. The signal transmitters are fixed on the ceiling in the building.

Szwedko et al. [5] presented a concept of a hybrid evacuation system using both RFID and QR-Code (Quick-Response Barcode). RFID readers are deployed nearby the exits of the building while each of the personnel has registered to have a RFID card. The readers connected to a back-end database sense and record the personnel's position. When fire takes place, the personnel uses his mobile phone to scan the wild spread QR-Code tags for web addresses (URLs) to access to the Internet for evacuation instructions.

Chittaro et al. [6][7] developed a location-aware 3D model to give evacuating instructions when building disasters occur. The system uses active RFID tags sending signals every 0.5 second. The concept of this system is similar to the HBFES. However, processing speed and signal communication of the mobile device are still the concerns.

Wireless sensor networks have been also considered for building fire evacuation system [8]. Various sensors such as ZigBee can be deployed nearby to each other to form a network [9] for sensing fire or escapees' positions. The sensed information is rapidly transferred through the network to the base station.

Most of the evacuation systems only provide evacuation routes according to the pre-installed path planning software and the coordinates in either front-end or back-end database. When the building fire spreads, the evacuation routes are possibly not accessible or very congested. This can be dangerous if re-finding another route is necessary. Therefore, an integrated system with location identification and external calculation functions is more satisfactory for fire evacuation.

Cloud Computing is the extension of distributed computing which combines internet applications. The concept is to divide user's data into multiple individuals, and then send to servers for execution. Cloud Computing helps servers share the work to process numerous data. Cloud computing can be divided into three segments as in Fig.1: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

There are many types of application related to Cloud Computing [10]. However, very few have been found in the study of remote calculation.

In this study, there are a number of advantages of applying Cloud Computing for the fire evacuation system, namely higher processing speed, larger storage memory, less risk when fire takes place, lower related cost, and higher capability for integration.

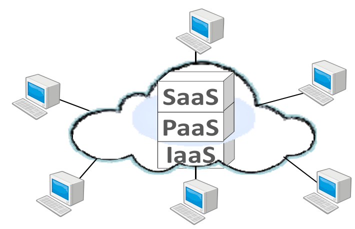

Figure 1. Cloud Service

III. SYSTEM ARCHITECTURE

The previous HBFES consists of the following subsystems:

- Active temperature RFID tags.
- A mobile phone with RFID reader.
- Software packages such as Viewpoint Calculator, Path planner, and MobiX3D.
- Back-end database.

In this study, the back-end database and all the software are moved to the Cloud Computing site as in Fig. 2. All the subsystems are described as follows.

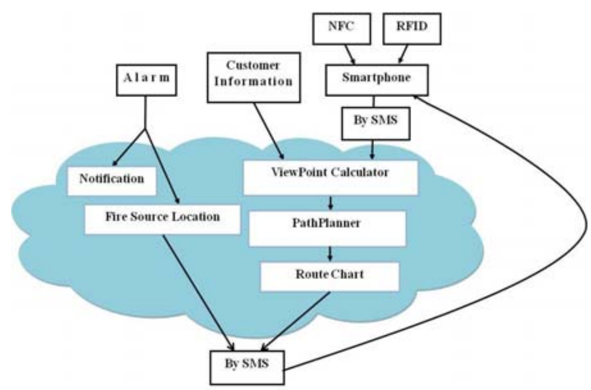

Figure 2. System architecture with Cloud Computing

A. Database

The database consists of the details of the registered members in the building, including the mobile phone number, or its identification. All the dimensions of the building such as emergency exits and evacuation routes are also input to the database.

B. Mobile phone

There are various types of smartphones with sophisticated operating system. Since there is none with a RFID reader, we assume an external RFID reader attached to a smartphone is used.

C. Viewpoint Calculator

Viewpoint Calculator is the software calculating the input data sensed from the RFID tags. This software is installed in the Cloud Service.

D. Path planner

- Path planner is the software calculating evacuating routes [1]. Once the person's location is verified as a "start point" of the path planning, the path planner will find the shortest distance to any of the emergency exits. The evacuating routes must be input in advance as well as the access points of temperature RFID. The optimum evacuation routes are calculated according to the fire condition, the distance to the exit, and the number of escaping people.

E. MobiX3D viewer

MobiX3D is the visual software installed on the smartphone to display the evacuating route [11]. All the integrated software is initiated when the control center sends a SMS to the escapee's mobile phone. After Viewpoint Calculator and Path planner find the evacuating routes, MobiX3D displays the paths according to the result.

F. Active temperature RFID sensor tags

An active temperature RFID sensor tag is a RFID tag with a battery connected with a temperature sensor transmitting real time temperature to the RFID reader for recording tag ID, time-stamp, and temperature [12]. The sensor tag operates at 2.45GHz of frequency with a temperature range -50℃ to 150℃, and 12 to 18 μA of working power .

IV. THE ALGORITHM OF FINDING THE EVACUATING ROUTES

The operating procedure is similar to the previous system:

- When fire takes place, the alarm system initiates the evacuation system to send a SMS message to all registered members and fire brigade. All the required personal details are recorded in a corresponding database. The mobile phone starts sensing RFID signals every 0.5 second, and sending back to the Cloud Service after receiving the SMS.
- The software, Viewpoint Calculator, Path planner, and MobiX3D viewer, are started simultaneously at the Cloud Service site to receive the RFID signals.
- After Viewpoint Calculator identifies the location of the mobile phone, Path Planner then decides the best evacuating route according to the shortest path and fire spreading conditions. This is the input for the software MobiX3D viewer to provide a 3D image of the evacuating route on the mobile phone.
- It is difficult to find the location of the mobile phone by calculating the signal strength from the RFID tags. The simplest and most effective method is to list all the sensed RFID tags and find the average coordinates. Thus, the location of the user holding the mobile phone is determined by the equation:

$$P(x,y) = \frac{\sum R(x_i, y_i)}{n} \quad (1)$$

Where $R(x_i, y_i)$ is the coordinate of the *i*th sensed RFID tag and *n* is the number of the sensed RFID tags.

With the same operating procedures, the algorithm of finding the optimum evacuating routes depends on the following factors:

- The distances to all exits.

The simplest method of determining the best evacuating route is to compare the distances to all possible exits. In Fig. 3, the temperature RFID tags are deployed at points A, B, and C. Points E, F, and D are the exits. Point O is the person carrying the mobile phone. Once the location of O is found, the shortest route is OBD to the nearest exit. This can be easily obtained by applying the following equation:

$$D_i = | E_i(x,y) - P(x,y) | \quad (2)$$

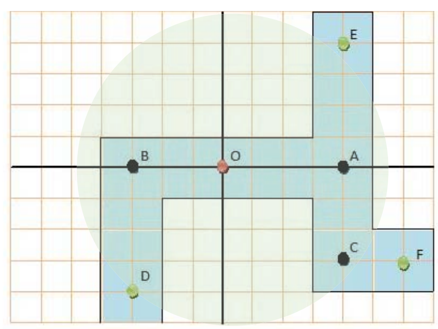

Figure 3. Escape illustration

- The sensed temperatures on the evacuating routes.

From Fig. 3, the best route is the shortest route OBD to exit D. However, the route may not be available due to fire or high temperature. A temperature cost was set to evaluate the evacuating route. For example, if tag B senses a temperature 2 ℃ higher than tag A and C, the route OBD with distance 7 units increases 2 units so that routes OBD and OACF have the same cost 9 units, i.e., the best route becomes OAE which has a cost of 8 units. If the sensed temperature is higher than 50 ℃, the cost is set to be infinity that the routes thru that RFID tag are no longer available. Thus, an equation can be applied for finding the temperature factor:

$$T_i = t_i - \min(t_j) \quad (3)$$

Where t_i is the temperature of the *i*th RFID tag, t_j are the temperatures of all the sensed RFID tags.

- The number of evacuating people on the same routes.

The number of the evacuating people can cause congestion at the exit [3]. The moving speed can be detected and calculated by the RFID sensors. If the congestion occurs, the number of people must calculate to estimate the evacuation time. This will be compared with another evacuating route to change the cost. For example, if the system senses that there are more than three persons nearby an exit, the cost should increase so another evacuating route becomes more appropriate.

Therefore, the equation to determine an optimum evacuating route is:

$$R_i = D_i + T_i + C_i \quad (4)$$

Where D_i is the distance factor, T_i is the temperature factor, and C_i is the congestion factor. Thus, the least of R_i is the optimum evacuating route.

There is no correlation found among those factors. Therefore we use a linear equation to simplify the system.

V. CONCLUSION

In this research, a RFID based fire evacuation system has been designed. Considering the effectiveness of a smartphone performing signal sensing and calculating, the back-end database is installed by applying cloud computing. Once a building fire takes place, the user with a smartphone and RFID reader can read the RFID data and transmit to the cloud service to calculate for an evacuating route. The algorithm of finding the optimum evacuating routes has been investigated. The factors namely distance factor, temperature factor, and congestion factor are considered to determine the optimum evacuating route. This algorithm should be applied in the cloud service which is capable for massive calculating for all the people in a building. In addition, it is difficult for many organizations situated in the same building to establish a common fire evacuation system. An external integrated system can be very helpful in terms of low cost and easy maintenance.

Another advantage of applying cloud computing is that the system can integrate the resources to create better efficiency.

However, hardware such as a mobile phone with a RFID reader is not available. It is difficult to predict what a new generation of mobile phone will be as it is marketing oriented. As a result, an external reader with a common interface such as Micro Secure Digital (Micro SD) will be necessary.

Another concern is that the Cloud Computing is not yet popular in this area. Most of the existing cloud services focus on the utilities thru the Internet. Mobile phone communication with Cloud Service will be another issue in the future work.

REFERENCES

[1] Liou Chu, “A RFID-Based Hybrid Building Fire Evacuation System on Mobile Phone”, The Sixth International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP-2010), Darmstadt, Germany, October 15-17, 2010

[2] F.M. Aymerich, G. Fenu, & S. Surcis, “An Approach to a Cloud Computing Network”, IEEE Xplore research, August, 2008, pp.113 – 118

[3] E. W. C. Lim, “Human Evacuation Modeling by the Discrete Element Method”, Defence, Science and Research Conference 2011 (DSR2011), Singapore, 3-5 August, 2011.

[4] Y. Inoue, A. Sashima, T. Ikeda, and K. Kurumatani, “Indoor Emergency Evacuation Service on Autonomous Navigation System using Mobile Phone”, Second International Symposium on Universal Communication, 2008.

[5] J. Szwedko, C. Shaw, A. G. Connor, A. Labrinidis, and P. K. Chrysanthis, “Demonstrating an evacuation algorithm with mobile devices using an e-scavenger hunt game”, International Workshop on Data Engineering for Wireless and Mobile Access, 2009, pp 49-52.

[6] L. Chittaro, D. Nadalutti, “Presenting evacuation instructions on mobile devices by means of location-aware 3D virtual environments”, Proceedings of the 10th international conference on Human computer interaction with mobile devices and services, Amsterdam, The Netherlands, pp 395-398, 2008.

[7] L. Chittaro and D. Nadalutti, “A Mobile RFID-Based System for Supporting Evacuation of Buildings” Springer Berlin / Heidelberg, Vol. 5424/2009 pp 22-31.

[8] Y.Zeng, S. O. Murphy, L Sitanayah, T Tabirca, T Truong, K Brown, and C Sreenan, “Building Fire Emergency Detection and Response using Wireless Sensor Networks”, 9th IT & T Conference, School of Computing, 2009.

[9] Y-M Cheng, “Using ZigBee and Room-Based Location Technology to Constructing an Indoor Location-Based Service Platform”, Intelligent Information Hiding and Multimedia Signal Processing, 2009. IIH-MSP '09. Fifth International Conference on, Issue Date: 12-14 Sept. 2009, pp 803 – 806, Kyoto.

[10] Qian, L., Luo, Z., Du, Y. & Guo, L. (2009), “Cloud Computing: An Overview”, Lecture Notes in Computer Science, Volume 5931/2009, pp 626-631.

[11] D. Nadalutti, L. Chittaro, and F. Buttussi, “MobiX3D: a player for displaying 3D content on mobile devices”, Mobile Guide 2006, Turin, Italy October 18, 2006.

[12] GAO RFID Inc., http://www.gaorfid.com/.