An Integrated Building Fire Evacuation System with RFID and Cloud Computing

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Abstract—**Building fire is a common disaster happening in our daily life that causes unfortunate casualties and deaths. Successfully escaping from fire depends on the design of evacuation route and time, as most of the damage of fire is caused due to lack of evacuation equipments or poor design of the emergency route. In this research work, we designed a hybrid building fire evacuation system (HBFES) on a mobile phone using Radio Frequency Identification (RFID) techniques and Cloud Computing. The system will be implemented at Tamkang University on Lanyang campus. Several existing computer or mobile phone applications, namely Viewpoint Calculator, Path planner, and MobiX3D viewer will be used on the system to rapidly calculate reliable evacuation routes when building fire takes place.**

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

I. INTRODUCTION

In modern society, building fire is one of the most common disasters causing casualties and deaths. The fire can spread quickly carrying strong heat and smoke that stop people escaping. A sophisticated design of evacuation routes can be very helpful as well as evacuation equipments when heavy smoke occurs. Normally, a modern building has a sophisticated designed central fire alarm system with temperature and smoke sensors. When fire takes place, the sensors will initiate fire alarm and indicate the places of the fire. Emergency exits are also designed with apparent indicators that people can follow. A well organized evacuation plan is also carried out according to the safety regulation followed by evacuation drill. However, people under a great pressure or a chaotic condition are easy to lose the ability of making decisions and recognizing orientations. Some people may lose their visions when smoke is built up, while others may be injured somewhere in the building. The escaping people may not survive when they lose their conscious. Therefore, any auxiliary equipment indicating their locations and displaying the evacuation routes to help people escape from fire as soon as possible is desirable.

Nowadays, the most popular personal electronic device is a mobile phone. Many of the existing mobile phones have build-in global positioning system (GPS) function from which the location of the mobile phone can be discovered as long as the signal is available. The GPS system transmits signals thru a number of satellites so the emitter can be precisely located. However, it is difficult to receive such satellite signals within a modern building. Therefore another location recognizing system becomes necessary.

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. This introduces an immediate problem. 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

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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. 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 same software such as Viewpoint Calculator, PathPlanner and MobiX3D viewer are used in the cloud computing service to carry out the designated tasks. 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 operating procedures, followed by the conclusion in the last section.

II. Related work

The existing evacuation systems have been developed by applying different technologies. For example, Inoue et al. [3] 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. Software for calculation and visualization on the mobile device helps finding the evacuating routes. The transmitter uses ordinary dry batteries to generate beacon signals as power consumption is relatively low. The battery power is estimated to be used for approximate half a year.

Szwedko et al. [4] 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. The advantage of this application is that both of the RFID and QR-Code sub-system are connected to the same back-end database. Therefore the two subsystems can operate concurrently and interchangeably. Each of the subsystem can perform as a fail-over for the other so the system becomes more robust. However, sensing a RFID card is more likely to be monitoring that might not be desirable. The sensed information is only provided for rescue personnel without any instant instructions for escaping people. If the RFID subsystem cannot function, it is difficult to determine the locations of the escaping people.

Chittaro et al. [5][6] 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 [7]. Various sensors such as ZigBee can be deployed nearby to each other to form a network [8] for sensing fire or escapees' positions. The sensed information is rapidly transferred through the network to the base station. The sensors consume very little power that ordinary batteries can maintain the use for a long time. This can be very significant when main power is not available. However, the route of the net is easy to be broken when building fire spreads, and the evacuation instructions become unavailable. In addition, the cost of sensors is also relatively high so that budget problems can be very significant if the deployed area is wide.

Most of the existing researches applied active signal generator, such as beacon radio signal transmitter, active beacon RFID tag, or sensor networks, to find the escapees positions and provide evacuation instructions. The major disadvantage is that when main power is unavailable, the system becomes unreliable. 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).

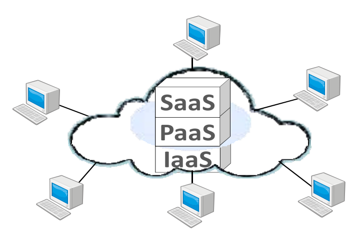

Figure 1. Cloud Service

There are many types of application related to Cloud Computing [9]. 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.

III. SYSTEM ARCHETECTURE

In the previous design of HBFES, the system consists of the following subsystems:

- Database in the central controlled alarm system.
- A mobile phone with RFID and Near Field Communication (NFC) reader.
- Corresponding software packages such as Viewpoint Calculator, Path planner, MobiX3D viewer, and LBS installed on the mobile phone.
- Active temperature RFID sensor tags on which locations and local temperature are recorded.
- NFC tags for indicating the escapee's position.

The architecture of HBFES is presented as in Fig. 2

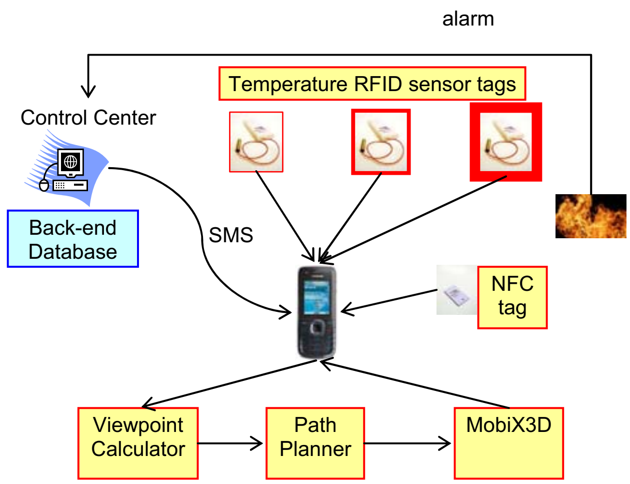

Figure 2. Architecture of the evacuation system.

In this study, the back-end database and all the software are moved to the Cloud Computing site as in Fig. 3. All the subsystems are described as follows.

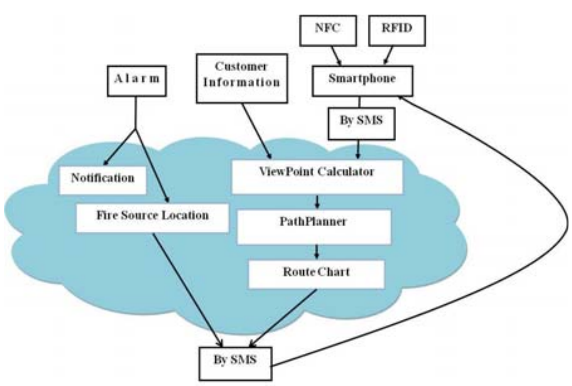

Figure 3. System architecture with Cloud Computing

A. Database

The database is used for recording the mobile phone numbers and the default locations of all registered members. When the fire alarm is triggered, the system sends a SMS (short message service) message to warn the members to be alert.

B. Mobile phone

There are various types of smartphones with sophisticated operating system. However, there is none with a RFID reader. In this study, an external RFID reader attached to a smartphone will be used. The smartphone must have a advanced processing speed and display software.

C. Viewpoint Calculator

Viewpoint Calculator is the software which searches signals and data from the RFID tags as input data. A robust method is to calculate the average distance from several tags. Since each tag has an unique coordinate, the calculator can easily find the location of the reader by calculating the average of the coordinates of the surrounding tags. When the NFC tags are available, the calculation for positions is not required.

D. Path planner

Path planner is software in planning evacuating route [1]. Once the person's location is verified as a "start point" of the path planning, the path planner will the shortest distance any of the emergency exits. The evacuating routes must be input in advance as well as the access points of temperature RFID. Temperature sensing gives the path planner "obstacle points" where the fire has spreads so the escapee should not take that route.

E. MobiX3D viewer

MobiX3D is visual software used in mobile device, displaying 3D content to provide user better interpretation and decision making [10]. The most common application is GPS on a mobile device. We integrated Viewpoint Calculator, Path planner, and MobiX3D on a mobile phone to find the optimum escaping route when building fire occurs. 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 [11]. The sensor tag operates at 2.45GHz of frequency with a temperature range -50℃ to 150℃, and 12 to 18 μA of working power . Since the working power is very low, the battery can provide the operation for 4 years. An active RFID tag can transmit signals up to 100 meters as it does not require external power. However, the sensing range of the active RFID reader on the mobile phone is 20 meters. Therefore, we decided to deploy active temperature RFID sensor tags every 30 meters since the escapee whose position is out of the sensing range of one tag, must be within the sensing range of another. The tag ID provides the coordinate so the software Viewpoint Calculator can decide the escapee's position.

IV. OPERATING PROCEDURES

The operating procedures of the integrated fire evacuation system are described as follows.

- When fire takes place, the alarm system initiates the evacuation system at the Cloud Service 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.

The best evacuating route is decided by comparison of distances to exits. In fig. 4, Points A, B, and C are deployed temperature RFID tags. E, F, and D are exits. Point O is the person carrying the mobile phone. Once the location of O is found, the best route is OBD to the nearest exit. However, the route OBD may not be available due to fire. If tag B senses the temperature 2 ℃ higher than tag A, the route OBD with distance unit 7 increases 2 units so that routes OBD and OACF have the same cost 9 units, i.e., the best route becomes OAE. 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.

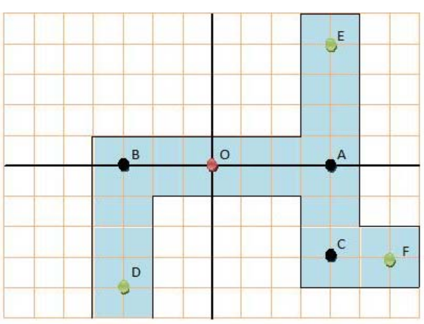

Figure 4. Escape illustration

Another advantege of applying Cloud Computing is that all the locations of escaping people can be detected. If two or more people are taking the same route, the system can increase their costs so that they can select the best or the second best route in order to avoid congestion.

V. CONCLUSION

This research is to re-design and the previous HBFES on a mobile phone assisting people evacuation from building fire. System design and evaluation have been carried out. In addition to the HBFES, this system integrates Cloud Computing as its calculation server so the performance is much better than before. The existing mobile phones still are not capable for an active RFID reader. Thus an external reader with a common interface such as Micro Secure Digital (Micro SD) is necessary. Another concern is that the Cloud Computing is not yet very popular. Communication problems with Cloud Service can be significant issue in the future work.

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