Sensors-Assisted Rescue Service Architecture in Mobile Cloud Computing

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***Abstract*— In this paper, we propose a sensors-assisted rescue service architecture to integrate rescue schemes for different purposes, including disaster prediction, evacuation planning, and emergency broadcast. In the proposed architecture, multiple-sensed mobile devices are designed to provide a personalized situational awareness, thereby further enhancing the flexibility and efficiency of rescue services. Reliability and scalability of rescue services are improved by leveraging the dynamical resource provision of cloud computing. The proposed rescue service architecture is implemented to show the advantages of power efficiency and scalability of the proposed rescue service architecture.**

***Index Terms*— rescue services, mobile sensing, cloud computing.**

I. Introduction

Rescue services play a crucial role in emergency circumstances in order to mitigate damage and rescue victims. First, emergency information should be collected quickly and accurately at an emergency scene. Then the information is delivered to rescue centers through fixed or wireless communication networks. Finally, rescue work is dispatched to the rescue team such as polices, fire fighters, and medical personnels according to the rescue planning and decisions.

Current rescue systems, such as E-911 services [1], require users to first make emergency calls to the rescue center as shown in Fig. 1. Then, the rescue center assigns the rescue work to the local rescue station. However, current rescue systems suffer from two significant problems. First, emergency information is collected and reported by individuals. In some emergency situations when a person is kidnapped or has an injury, he/she is unable to activate rescue services or report emergency information clearly, e.g., making emergency calls by hands or even by mouths. Second, a rescue center becomes a bottleneck for a large-scale emergent events. In other words, current rescue systems do not ensure the scalability and reliability in massive casualty environments. A painful experience we learned from the attack on the World Trade Center in New York, on September 11, 2001 is that heavy emergency call caused sudden and severe congestion in the phone system,

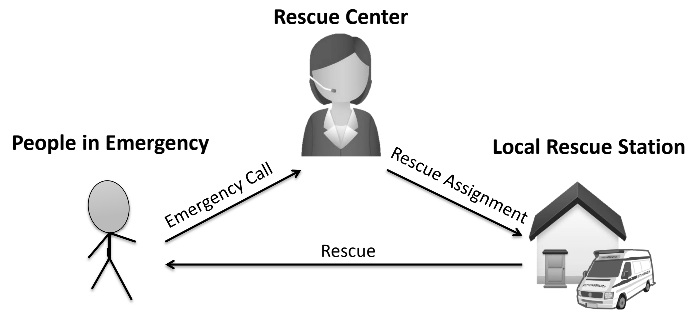

Fig. 1. Current rescue system .

preventing the quick and efficient gathering of emergency and damage information by government authorities. As a consequence, the delayed rescue may cause further casualty that could have been prevented.

To solve the aforementioned problems, we propose a mobile-sensing cloud (MSCloud) rescue service architecture that incorporates multiple-sensed mobile devices, such as iPhone or Google Glass [2], with cloud computing. Recently, with many sensors, such as visual, audio, motion, location, ambient, and physiological sensors, current mobile phones can sense the situation information of local environment and the behavior status of users. Inspired by wireless ad-hoc and sensor networks (WASNs) that have made significant contributions in surveillance and health care, we propose the concept of personalized situational awareness by using multiple-sensed mobile phones in our rescue architecture for automated monitoring and updating personalized emergency information. Contributions and novelties of this work are listed as follows:

- A flexible sensing scheme for emergency response is proposed to improve the efficiency of rescue services by providing personalized situational awareness through the integration of mobile devices and sensors.
- The proposed architecture can improve the reliability and scalability of rescue services by leveraging the resources and the dynamic scaling of cloud computing.
- Provide a framework to integrate rescue services with a global vision from different aspects of various rescue systems.

This article aims at giving an overview on the MSCloud architecture and shows the proof-of-concept implementa-

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tion results based on the example of personalized earthquake rescue assistant (PERA). The rest of the paper is organized as follows. Section II describes recent efforts for rescue services. Section III details the proposed sensors-assisted rescue service architecture. Sections IV and V show the implementation design and the experiment result of PERA, respectively. Related research issues of integrating multiple-sense mobile phone and cloud computing are discussed in Section VI. We give our concluding remarks in Section VII.

II. Related Work

Research in the area of emergency rescue services fall into three categories: (1) disaster prediction and prevention, (2) evacuation/rescue planning, and (3) emergency response and broadcasting. First, disaster prediction and prevention plays a key role in an effective mitigation of disaster. Building an accurate disaster prediction and prevention model is important to reduce casualties and prevent disasters from occurring. [3] and [4] proposed a flood forecasting technique that is based on an artificial neural network (ANN) model. In [5], the Multivariate Compound Extreme Value Distribution (MCEVD) was applied to predict typhoon-induced extreme disaster events. Second, evacuation/rescue planning focuses on immediate decision for rescue action and evacuation route. For example, given a transportation network with capacity constraints and geographic information, evacuation route planning determine refuges and a set of evacuation routes as well as a schedule for the movement of people and vehicles along these routes, such that the evacuation is completed in the shortest time. [6] presented an optimization modeling technique to develop an evacuation plan for bus routing and passengers pick up points during the hurricane. To calculate reliable evacuation routes when building fire takes place, [7] designed a hybrid building fire evacuation system using Radio Frequency Identification (RFID) techniques. [8] developed a heuristic method called the Incremental Data Structure (IDS) that reduces the computational cost of the evacuation planning algorithm by reducing the total cost of shortest path computation. Thirdly, emergency response and broadcasting seek to efficiently gather accurate emergency information and timely deliver response to rescue authorities. [9] and [10] constructed Wireless Sensor Networks (WSN) to achieve efficient disaster response. [11] designed a data collection framework with sensor networks to collect and transmit damage data from various devices deployed in buildings.

Instead of focusing on the above techniques in emergency rescue services, our work proposes a new rescue service framework which incorporate multiple-sensed mobile devices and cloud computing to provide a more convenient and efficient rescue services. Our proof-of-concept implementation shows that the proposed framework with the above techniques can achieve better performance in large scale of disasters.

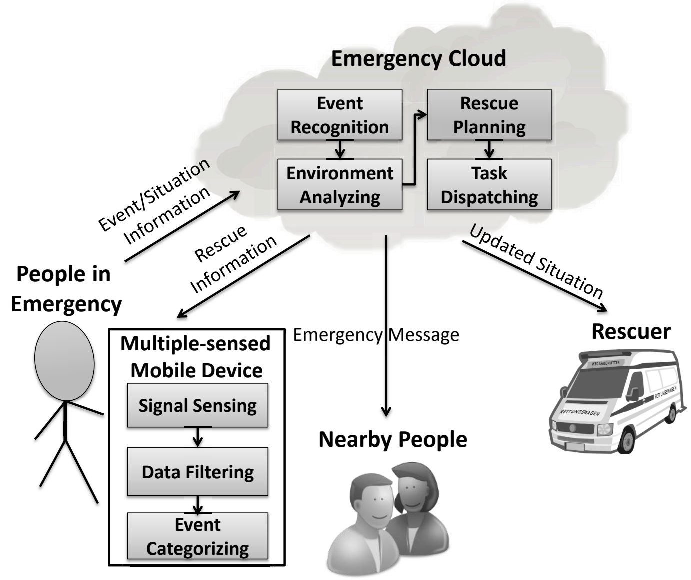

Fig. 2. System architecture of MSCloud.

III. MSCLOUD System Architecture

MSCloud is a rescue service architecture that incorporate mobile device and cloud computing. Fig. 2 shows the system architecture and related system components of MSCloud. The designed architecture is composed of multiple-sensed mobile device, emergency cloud, nearby people, and rescuer. The following subsections detail the functionality of the four components.

A. Multiple-sensed Mobile Device

Our system relies on multiple-sensed mobile device which can collect a wide range of sensing data from the environment or the behaviors of people. These sensors, such as visual, audio, motion, location, ambient, and physiological sensors, collect valuable personal data for rescue authority to make decisions when an emergency occurs. First, signal sensing should be processed in an automated manner to detect the unexpectedly emergency event. We then filter these sensing data to extract meaningful information. Information is considered to be an emergency event if it contains predefined pattern. Finally, events are categorized according to user-defined criteria and send to emergency cloud.

B. Emergency Cloud

Since the event information from mobile devices is generated from a local perspective and may be incomplete since the sensing is done in an emergency situation, emergency cloud have to further recognize the complete event with a universal perspective. Then, the environment within the range of emergency event is analyzed with environment data to support rescue planning. For example, emergency event in urban district and mountain area may have distinct rescue method and policy. In addition, a rescue information, such as the shortest path to the shelter, that give people in emergency a guidance is sent to mobile devices. Finally, emergency cloud dispatches the rescue tasks to appropriate rescue units according their work loading and locations

C. Nearby People

It is possible that somebody near the people in emergency can provide more instant help than distant rescue units. Thus, we broadcast the emergency message to nearby people. Furthermore, a prediction or evacuation of a disaster often needs to broadcast the emergency message to people in a local area.

D. Rescuer

Mobile devices will keep updating the situation information of people in emergency to the cloud after sending event information. The situation information will also be analyzed and updated to give rescue units an immediate information.

IV. Personalized Earthquake Rescue Assistant (PERA)

Many people died in Jiji/Taiwan earthquake since they are unable to communicate with rescue authorities or have no chance to be rescued in time [12]. Thus, we design and implement PERA, which is also considered as a proof-of-concept system that is developed to demonstrate the proposed MSCloud architecture. Fig. 4 shows the system architecture for the proposed PERA.

A. Client Side

For the client side, the service is designed to run in the background. Two rescue service initialization schemes are developed: motion-driven sensing scheme and voice-driven sensing scheme. Two steps for rescue service initialization are designed for both schemes. First, motion activation is to determine whether the rescue mechanism should be triggered or not. A user can take and shake his/her smart phone to trigger this event (by voice volume sensor and proximity sensor). Second, the gesture recognition step is designed to recognize user's finger motion according to their predefined personalized gesture. For the voice-driven sensing scheme, the first step is to activate the volume detection, measuring the volume level (by voice volume sensor) and the vocal frequency of users, and then triggers the voice record mechanism when the sensed value reaches the threshold. Thus, people can use speech recognition technique without touching the small record button on the phone screen. Finally, people in emergency can initiate rescue service by speaking the predefined keyword with the help of speech recognition. For example, people trapped in the disastrous areas under collapsed buildings who are unable to touch his/her mobile phone can use voice-driven sensing scheme to call for rescue. Fig. 5 illustrates two proposed sensing schemes. After a user activates any one of the two sensing schemes, the system will send rescue

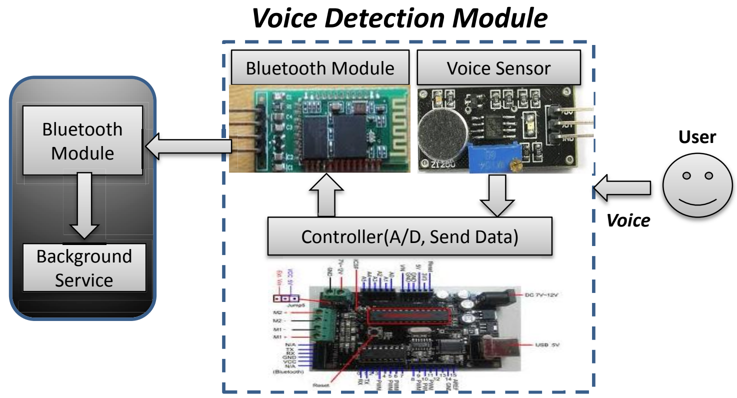

Fig. 3. Voice detection module in PERA.

message instantly and keep updating GPS location data, the pictures of the local environment, and the record of the voice to PERA cloud platform.

We use HTC Desire as the mobile platform for implementing PERA. The OS system of Desire is Android 2.1. However, since voice volume sensor are not built-in in current smart phone, we use Bluetooth to link the sensor and mobile devices. The hardware components of PERA consist of (1) smart phone, (2) arduino board, (3) voice sensor, and (4) Bluetooth module. Fig. 3 illustrates the relationship of these four modules in our system. The voice sensor detects the volume level from surroundings with A/D converter (Arduino Board) and transfers data via Bluetooth module. We also integrate proximity sensor, accelerometer, orientation sensor, and GPS module to detect the users' motions.

B. PERA Cloud Platform

PERA cloud platform provides earthquake prediction/prevention computation based on neural network technique [13]. Message for alerting possible earthquake will broadcast to people who are in the range of affected area. After people calling for rescue, evacuation and rescue route planning, which aims at minimizing evacuation and rescue time and balancing the traffic flow on each route, will be performed instantly by dynamic programming according to the situation information provided by the people and the environment data [12]. Rescue route will be updated to rescue units continuously based on the situation of the people. Then we broadcast emergency message to the friends of the people in emergency by analyzing the social data from social networks. Specifically , we apply push notification service such as Android Cloud to Device Messaging (C2DM) [14], which provides a simple, lightweight mechanism for mobile devices to contact the server efficiently to fetch updated information.

V. Performance Evaluation

A. Power Consumption for Mobile Device

Since users have to run the proposed PERA service in the background of their smart phones for an unex-

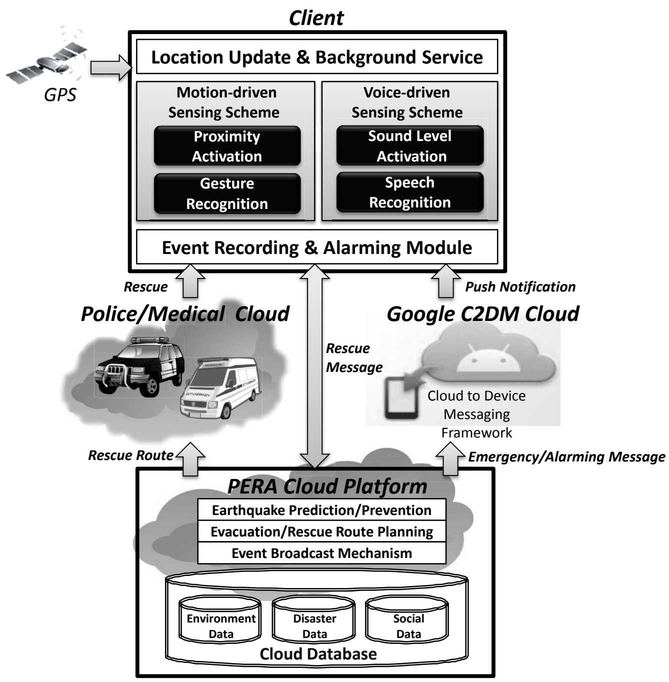

Fig. 4. System architecture of PERA.

Fig. 5. (a) Motion-driven Sensing Scheme (b) Voice-driven Sensing Scheme.

pectedly emergency, it is worthwhile to investigate the power consumption of the proposed rescue systems. Our experiments were conducted with the whole rescue system running in the background. The GPS module update the latest location every 30 minutes. Fig. 6 shows the power consumption for the standby mode and the rescue mode. One can observe that the proposed rescue system have nearly negligible extra power consumption (5% for most) to the phones.

B. *Delay Performance for Cloud*

To evaluate the performance improvement of migrating rescue system to the cloud, we conducted the experiment

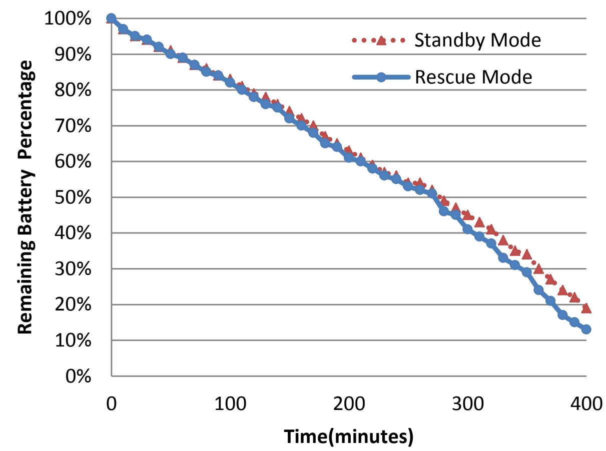

Fig. 6. Power consumption of PERA.

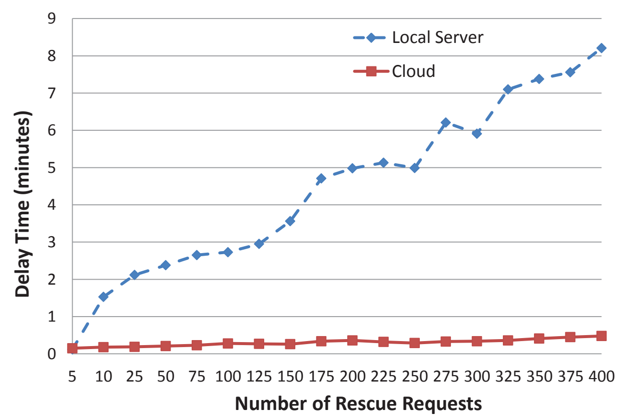

Fig. 7. Comparison on delay performance of PERA between cloud and local Server.

of running rescue route planning on Amazon Elastic Compute Cloud (EC2). The local server is equipped with an Intel Core i5 processor running at 2.4 GHz, 8 GB of RAM. The rescue route planning runs a dynamic programming algorithm to compute the fastest rescue route to the disaster spots according to the real-time road status information [12]. Delay time is measured by the calculation time of rescue route planning. Fig. 7 shows the delay comparison of PERA between cloud and the local server. We can see that the cloud provide lower delay even when the number of rescue requests increase. The ability of auto-scaling makes cloud suitable for handling large-scale of disasters.

VI. Associated Research Issues for MSCloud

Figure 8 shows the associated research issues for multiple-sensed mobile device, robust mobile wireless networks, and emergency cloud for the proposed MSCloud.

With the advance in sensing techniques , mobile devices are able to collect more sophisticated sensing data such as electroencephalogram. Thus, it is worthy to further research for sensing technique that provides personalized situation-aware service considering power efficiency. In addition, another critical issue is the privacy protection since

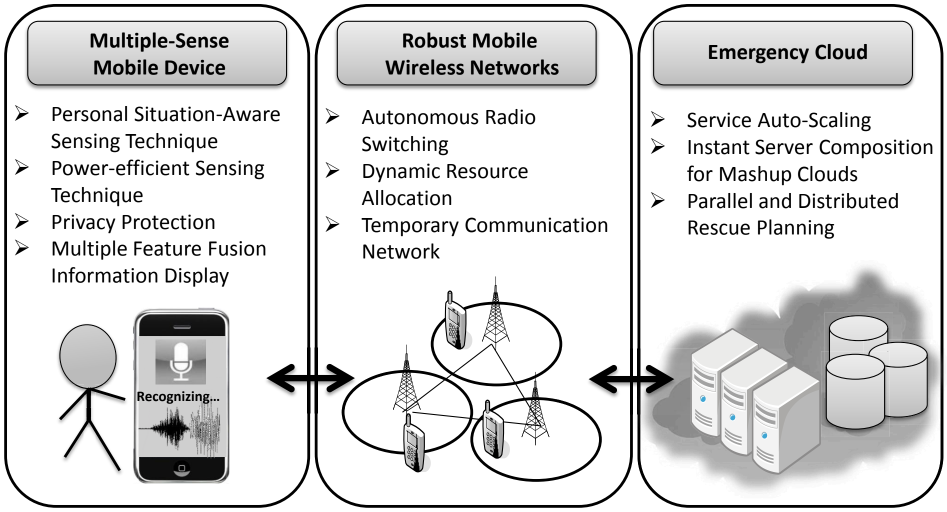

Fig. 8. Associated research issues for MSCloud.

lots of sensitive information, such as location data and physiological data, are delivered to cloud service providers [15]. Finally, rescue or emergency alerting service should be integrated with multiple features in a mobile device, such as augmented reality for evacuation route guideline [16].

Mobile devices rely on communications networks to access emergency cloud. However, fixed or mobile communication networks were usually down during disasters, which caused the rescue operation extremely difficult. In Jiji earthquake, ChungHwa Telecom, the largest telecommunication operator in Taiwan, took 15 days to restore the whole mobile communication systems. Therefore, robust mobile wireless networks with the ability of supporting heavy traffic during the emergency play a significant role in rescue services. First, since the rescue information needs to transport through the networks with minimum latency, autonomous radio switching is necessary, which allows each user to always connect to the best channels in several available radios and makes the system more robust to unanticipated workload increases in heterogeneous wireless network, including access discovery, radio selection, and seamless handover [17]. Moreover, rescue information which contains data with different constraints in terms of delay, jitter, packet error/loss rate, and bandwidth should be transmitted with higher priority. A dynamic resource allocation scheme is essential to optimally transmit the rescue information subject to the required priority protection [18]. Finally, a temporary communication network that supports emergency communications and information networks need to be constructed instantly if the entire communication system is crashed [12].

As we have shown in the experiment result, cloud computing brings the benefit of auto-scaling that increases the scalability of rescue service. Besides, emergency cloud has to exchange heavy information between databases among different clouds, which involve data networks and telecommunications networks. A instant server composition for mashup clouds is important for such event-driven service, i.e., services interact through events rather than through the classical call-response paradigm [19]. At last, rescue planning is data and computation intensive especially in large scale of disasters [8]. Therefore, a distributed and parallel algorithm for rescue planning is worthwhile to further investigate to fit into the parallel programming infrastructures, such as MapReduce, and distributed storage system, such as Hadoop, of cloud computing [20].

VII. Conclusions

In this paper, we proposed a sensors-assisted rescue service architecture that incorporates multiple-sensed mobile devices and cloud computing. Multiple-sensed mobile devices are applied in the proposed architecture to provide a personalized sensing schemes that can further improve the flexibility and efficiency of rescue services. Also, we improved the reliability and scalability of rescue services by leveraging the resources and the dynamic scaling of cloud computing. Implementation and Experiment results also showed that the proposed architecture is practical and effective. Our work integrated fundamental rescue efforts that are currently scattered and provide a new paradigm for rescue services.

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