Hybrid Radio Frequency Identification System for Use in Disaster Relief as Positioning Source and Emergency Message Boards

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Abstract. We developed a system that uses radio frequency identification (RFID) tags both as the source of location information and as data storage units to record messages or information in disaster situations. Our system uses hybrid RFID tags, which consist of a passive (non-battery) tag and an active (battery-driven) tag. The system has been evaluated in disaster prevention trainings by local communities and rescue teams.

Keywords: RFID, Rescue, Disaster Relief, GIS, Triage, Ad-hoc Network

1 Introduction

If a large-scale disaster strikes the telecommunication infrastructure, people will only be able to exchange information via "non-transmission" routes, that is, by "communication on the spot". In the aftermath of the Great Hanshin-Awaji Earthquake that hit Kobe in 1995, for example, paper bills were widely posted as a means of exchanging or distributing information in the disaster-afflicted area.

Information about evacuations, residents' safety, and emergent risk assessments were directly posted on damaged buildings in Kobe. The disaster in Kobe highlighted the importance of establishing a system that can be used in rescue operations to rapidly collect and disseminate information throughout an affected area. Such a system might rely on manpower, rescue robots, or other elements independent of day-to-day means of telecommunication. This system would prove particularly important in the event of a large-scale disaster that would likely cripple the telecommunication infrastructure. Of course it is important to create a robust telecommunication infrastructure, but "communication on the spot" is the most reliable way of communicating. Therefore, research on information technology for "communication on the spot" is extremely important to emergency response information technology.

To develop electronic "communication on the spot," memory devices such as message boards and message uploading and downloading devices such as pens should be used. Uploading and downloading should be possible without devices having to make physical contact, that is, by wireless communication, e.g., HomeRF, Bluetooth, or ZigBee. However, memory devices for message boards should be inexpensive because they must be widely distributed in disaster-afflicted areas. Radio frequency identification (RFID) technology is both non-contact and inexpensive, making it ideal for such a system.

RFID tags are small devices that can store, input, and output data without coming into physical contact with other devices. In addition to their wide use in non-contact IC cards, RFID tags are on their way to becoming commercially feasible for attachment to merchandise and cargo in the logistics industry. In addition to logistics applications, a range of uses in other fields, including firefighting and disaster prevention, were recently highlighted in a report by a study group [1] organized by the Ministry of Internal Affairs and Communications of Japan.

This report describes development of an emergency communication system in which RFID tags are used as location indicators and as emergency message boards. The RFID reader-writer is designed to read or write rescue-related information to or from an RFID tag. Such a device could serve as an information resource for rescue work in a disaster area.

2 Discussion of RFID system use in emergency response

The RFID system consists of a small tag that transmits ID information and a device that reads and writes ID. The passive (non-battery) RFID tag is supplied with electric power by the reader-writer via electromagnetic waves or induction. The passive tag is inexpensive and maintenance-free, so an enormous amount of tags can be distributed. The passive RFID system is superior to a barcode system because RFID tags have greater storage capacity and their functioning is not degraded when they become dirty. Moreover, IDs on tags in most passive RFID systems can be written and erased repeatedly. The problem with a passive RFID system is that the readable range between tag and reader-writer is quite short, so the reader-writer has to be relatively close to the tags to send or receive data. Moreover, the reader-writer has to radiate energy continuously in order to provide power to tags. Therefore, the reader-writer consumes a lot of power. In Japan, the radio frequency bands assigned for passive RFID system are under 135 KHz. 13.56 MHz, 950 MHz. 2.45 GHz (which is shared with wireless LAN and Bluetooth), and 5.8 GHz.

Active (battery-driven) RFID tags periodically transmit ID beacons. Most active RFID tags can transmit unchangeable ID, but stop transmitting when the battery fails. Most active RFID systems use the 300 MHz band. The advantage of an active RFID system is that the readable range between tag and reader is long. The active RFID reader can pick up an ID beacon from 10 to 100 meters away from the tag.

RFID systems have recently become popular in the domains of personal identification and for retail and logistics Point Of Sales (POS) systems. We believe that an emergency response RFID system should be different from such conventional RFID systems in the following two ways:

(1) In general, reader-writers are installed in the environment, and people carry RFID tags. In contrast, in an emergency response system, RFID tags should be distributed in a disaster area, and people should carry reader-writers because a complicated system installed in the environment might not function in a disaster situation.

(2) The RFID tags used in client-server systems are generally used only as identifiers, and the server retrieves information from an online database under its control via a network using the read ID as a key. An emergency response RFID system, in contrast, should be designed to use RFID tags for data storage, with all necessary information written in each RFID tag. This is because, with client-server-based information sharing using conventional telecommunication networks, it is impossible to call up and acquire needed information if a large-scale disaster leads to breakdowns or congestion in the telecommunication network.

Here, we discuss the advantages of a writable RFID system over handwritten messages in emergency situations. Handwritten messages are extremely cheap, easy to input and recognize, and require no special devices. Paper for the message can be obtained anywhere. However, handwritten messages are not easy to copy, deliver, and store. That means they're not good for collecting and sharing large amounts of information in a short time, which would be necessary in a disaster situation. Moreover, it's impossible to control access to handwritten messages. In other words, anyone, including malicious people, can read, replace, or overwrite them. Functions that set security levels or prioritize information are indispensable in leaving messages for specific people or in efficiently selecting important or relevant information from a huge number of messages. An RFID system will enable information to be quickly and accurately collected. RFID tags are much smaller than handbills with written messages. The information on tags is invisible, so security can be assured by using ciphers. Writers' identities can be verified by authenticating their writing devices. Such a means of guaranteeing security is especially important in disaster situations. However, a special device is required to read or write messages. The time and effort needed to input data seems to be about equivalent to handwriting. Passive RFID tags have become cheaper, but they are not available everywhere now. Therefore, RFID tags must be stored in advance for use in disasters.

In an actual disaster, both message boards with handwritten paper messages and RFID tags should be used. Messages should be written in both media. At first only handwritten paper would be left and then later RFID tag messages could be stuck beside the paper. In such a way, handwritten messages can be easily delivered and stored.

To be effective in emergencies. RFID reader-writers must be popular and easy to carry. Therefore. reader-writers must be miniaturized and user friendly. Moreover, RFID tags should be applied both for emergency response and for other purposes. That is, the emergency response RFID system should be developed to be easy to use and to have applications other than emergencies.

3 Overview of RFID System Hardware

The proposed system consists of portable reader-writers and passive RFID tags that function as information-storage units. Information is remotely downloaded onto or uploaded from the tags by the reader-writers. As mentioned in the previous section, miniaturization of the reader-writer is important. Figure 1 shows how the reader-writers have become more compact: cart-mounted (fiscal year 2001). backpack-mounted (fiscal year 2003), and handheld (fiscal year 2004).

Fig.1 Progress in miniaturizing RFID reader-writers.
(Left: FY2001. Center: FY2003. Right: FY2004)

In our system. passive RFID tags are used as information-storage units. Our passive tags use the 2.45 GHz band and have 128 bytes of memory. The tags are manufactured by Intermec Technologies Co. As mentioned in the previous section. the problem with a passive RFID system is that the readable range is quite short. While some RFID reader-writers are already commercially feasible for use as hand-held inventory terminals. most such terminals can only read an RFID tag up to several centimeters away. as with barcodes. However, assuming the necessity of reading a difficult-to-reach RFID tag in the event of a disaster (such as one buried under rubble). extension of the readable range is necessary. When the development process began. we attempted to make a device with the longest readable range possible with the passive RFID technology then available in Japan (about 2 meters). To do that a high-output stationary reader-writer requiring a private radio station license was modified and rendered portable by adding batteries,. However, since miniaturization is critical for mobile activities in disaster areas, a low-output device was adopted in fiscal year 2004. The new low-output reader-writer has a readable range of about 50 centimeters.

The reader-writer must also accurately detect a lot of tags in a disaster area. Therefore. in fiscal year 2005, we adopted a hybrid tag. which consists of both an active and a passive RFID tag, for use in our system. Figure 2 shows the hybrid tag. The active RFID tags act as radio beacons. Rescue workers in disaster areas carry RFID reader-writers, find beacons from active tags, approach the passive tags, and write or read disaster information to or from the passive tags. The active tags are manfactured by RF CODE Inc. The active tag transmits a weak periodic beacon signal on 303.825 MHz that the reader can pick up at a distance of about 10 meters. Figure 3 shows our most recent hybrid RFID reader-writer. The picture on the left of Figure 3 shows the front of the system: a PC with the PC card of a passive RFID reader-writer, and the picture on the right shows the rear: an active RFID reader unit and battery.

Fig. 2 Hybrid RFID tag
Left: Passive tag
Right: Active tag
(12.5 square centimeters)

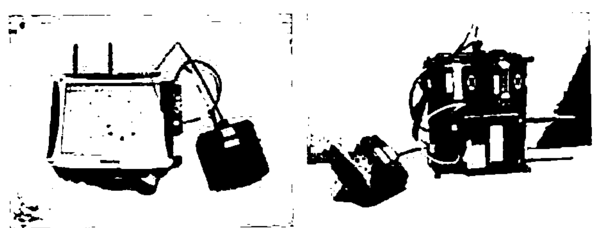

Fig. 3 Hybrid RFID reader-writer
(developed in FY2005)

The passive RFID reader-writer and the active RFID reader unit are connected via LAN cable. When the terminal reads the beacons of active tags, the IDs appear on screen and an alarm sounds.

4 Overview of RFID System Application

The paper on which messages are written in disaster situations is not originally intended for that use. People use paper that was originally advertising flyers for markets, business letters, school paper, and so on. This suggests that the system for emergency response should also be flexible. Therefore, in the RFID system's first stage, it should be equipped only for the fundamental function of reading and writing messages. After that function has been developed, the system should be used for more speculative purposes, such as feeding back the findings of rescue teams and public investigators to the information-gathering part of the system. Such a "market pull" approach will be more effective than a "technology push" approach in popularizing the system.

Hereafter we focus on showing examples of the kinds of information that an RFID system in a disaster area can exchange. Of course, our RFID system is not limited to the following examples.

*Message board:

*Messages for rescue teams:

Information on rescuing victims from collapsed houses can be provided to rescue teams. This information may also be helpful in rescues in other places.

*Message exchange for citizens:

Locations of refugees and relief services. and confirmations of individuals' safety can be provided to the public.

*Information on buildings:

Conditions of buildings damaged by fire or earthquake or emergent risk assessments of damaged buildings can be posted.

Disaster areas are confusing. and it is necessary to search for victims. and control and record rescue operations efficiently. In major disasters. teams must conduct medical triage, which is the process of prioritizing medical treatment and evacuation. During triage, paper tags indicating levels of priority are attached to victims. Our RFID system can support triage by reading triage tags. The number of victims remaining in a first-aid station would be easily determined by counting the number of active tag beacons. aiding in the emergency evacuation process. The RFID system would also help in investigation of accidents. For example. in a train wreck in Amagasaki. Japan in April 2005 in which more than 100 people were killed. information on positions of several victims in train cars was lost during the confusing rescue operations. Precise investigation of the accident was not possible because the scene was disturbed. If our RFID tags had been attached to victims and to rescue locations. it would have made a more precise investigation of the accident possible.

To implement the applications mentioned above, we have developed the following fundamental functions since fiscal year 2001:

* Simplified write function

Writing Japanese character strings to a single RFID tag, an operator inputs characters on a screen window, and the sequence of the character codes is written into a passive RFID tag. This supports the tag's basic function as a message board.

* Read function

Reading Japanese character strings from an RFID tag and saving them to a control PC. When more than two tags are read simultaneously. all data on the tags will be saved on the PC.

* Read-out function

Voice synthesis of Japanese character strings read from an RFID tag in real time.

* Write function

Automatic location of an empty tag among multiple RFID tags and writing of information to the empty tag.

* Retrieval function

Deletion of data on RFID tags and reuse of tags for other data.

* Announcement of conditions via voice synthesis
* Reading and writing binary data function

To deal with both message board and other application data, the system will also read and write binary data.

* Writing and retrieving binary data division function

To write data in excess of the capacity of a single tag. the system divides the large data into several segments and writes them into several tags each. The system reads data from the several tags and then merges and restores the data into its original form.

In the near future, we plan to implement the following fundamental functions.
* Data encryption function
* Access control function

Based on the fundamental functions mentioned above, we have implemented the following two functions for use in disaster relief:

1) Rapid safety inspection of damaged buildings

After a large-scale earthquake, architects inspect damaged buildings in the disaster area. We have developed a function to write and read assessment results to or from an RFID tag. This function is intended to check previous building data against current status to speed assessment of damage. The user inputs the grade of a building's incline and other data, and the application classifies the buildings into three risk categories: dangerous, requiring special attention, and safe. Assessment results are electronically deposited on-site for use by other rescue teams, thus avoiding duplicative investigation, streamlining relief subsidies, and contributing to the timely establishment of a detailed disaster database. Figure 4 shows a questionnaire form used for rapid inspection of the safety of a damaged building.

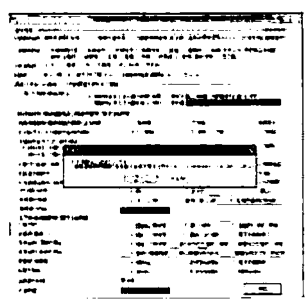

Fig. 4 Questionnaire form used for rapid safety inspection of damaged buildings.

Fig. 5 Image of GIS screen and RFID reader-writer interface.

2) Field damage information collection using a geographic information system

We combined our RFID system with a field damage information collection system that incorporates a geographic information system (GIS). The field damage information collection system was developed by Kogakuin University [2] and the National Institute of Fire and Disaster [3]. To use the system, investigators point to locations represented on the GIS screen and input information about collapsed buildings, fires, and road blockages at that location. The GIS displays our RFID reader-writer on the screen, and the data from the GIS is transferred to RFID tags. The combined system can pinpoint a worker's present position using the connected global positioning system (GPS). Figure 5 shows a screen image of the GIS and RFID reader-writer interface.

5 Experimental Results

In fiscal year 2002, development of the system has evolved as one of the themes of the Special Project for Earthquake Disaster Mitigation in Urban Areas (hereafter referred to as "the DDT Project") launched by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) [4]. Other DDT project efforts include field experiments and training exercises for rescue robots. Our RFID system has also been used in field experiments and training exercises. These experiments and exercises evaluated the system's performance and clarified the system's strengths and weaknesses. In the following section, we describe two of these field experiments.

5.1 Disaster Prevention Training Field Surveys

We tested our system in a community disaster prevention training exercise in September 2006. During the test, pictures of collapsed buildings were posted in different places in the test area. A hybrid RFID tag was attached to each poster. Two investigators carrying PC terminals with RFID reader-writers evaluated the level of damage to the buildings in each poster. The investigators input their inspection results into the terminals and RFID tags. Figure 6 shows a poster and a tag being accessed by an investigator.

Fig. 6 Field experiment in a disaster relief training
(Sep. 2006, Kamijujo, Tokyo)

During the test the readers were able to detect active tags at a range of between 4 and 6 meters. This shows that the active tags help the readers find the passive tags. This range will help avoid interference between beacons. However, if the tags are buried under rubble, this range may not be adequate. An avalanche rescue system with both non-battery and long-range tags has already been commercialized [5]. The tags for the avalanche system may be better for our system than the ones we currently use. We also plan to measure radio intensity of RFID systems of various radio frequency bands in an electric wave darkroom. The results of this measurement will show whether our readers can detect RFID tags that are buried in rubble.

The following problems emerged during the field experiment: it is hard to operate the terminal, the terminal is too heavy, the liquid crystal display is not clear, and the alarm that sounds when an active tag beacon is detected is hard to hear. These problems can be easily solved.

5.2 Messages for Follow-up Rescue Teams

In April and October 2006, our system was used in training exercises that simulated a situation in which disaster victims were trapped in a collapsed house and rescued by robots. In the exercises, after the victims had been rescued, members of the rescue team put hybrid RFID tags on the entrances of dummy collapsed houses. Information about the rescue work was stored in the tag, and the information was shared with the following rescue team or investigator. In June 2006, our system's performance was also evaluated in a rescue training exercise that simulated an act of nuclear-biological-chemical terrorism. Figure 7 shows pictures of the trainings.

Fig. 7 Rescue workers placing our RFID system tags at trainings.
Left: Hybrid RFD tag being placed at entrance of
a dummy collapsed house by rescue worker .
Right: Message being read from tag by a follow-up investigator.

A rescue team member who participated in the experiments commented on our system as follows: Although installing a tag does not hinder rescue operations, it is difficult to use the present terminal for data input. In order for a rescue worker to operate the reader, the reader must be robust and operable by people wearing gloves.

6 Discussion and Conclusion

We have been attempting to further miniaturize the reader-writer. We are planning to replace the active RFID reader unit with a PC card by the end of the current fiscal year. The PC that controls the passive and active RFID reader-writers is operated by Windows XP, so a more compact PC, e.g. a PDA, can be used for our system. However, the PDA's screen may be too small for rescue workers wearing gloves to operate the GIS screen.

Currently, our system is intended only for use in times of disaster. However, as RFID systems come into wider use, we plan to develop the RFID system to become more broadly applicable to areas such as fire and crime prevention. Therefore, a new research and development project called RFID-based Positioning Systems for Enhancing Safety and Sense of Security. also promoted by MEXT. was started during this fiscal year.

Technology not used in normal situations will not be used in emergency situations. On the contrary, if an emergency response function is incorporated into popular equipment, the function will become more popular. In Japan. most cellular phones have built-in cameras and barcode readers. If the RFID reader-writers are also built into cellular phones. and RFID applications come into daily use. the applications described in this article have a better chance of success. We are currently collaborating with a Japanese cellular phone carrier to build an RFID reader into a cellular phone.

Acknowledgments

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Thursday, February 22, 2007

[redacted]

Registration

Welcome

Keynote Speech:
Kees Nieuwenhuis, ISCRAM Conference Chair, DECI[redacted]
Lab, Netherlands

Session 1: Medical Services

[redacted]hierry, S. Grasser — Aspects of Anatomical and Chronological Sequence Diagr[redacted] in Software-supported Emergency Care Patient Report Forms

[redacted]Zuliani, E. Carchiett — Mobile Devices in Emergency Medical Services: a PDA-bas[redacted] System for Ambulance Run Reporting

[redacted]hierry — Feasible Hardware Setups for Emergency Reporting Syste[redacted]

Lunch

Session 2: Team Support