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# 3 Ubiquitous Communication Technology for Disaster Management and Mitigation

## 3-1 Ubiquitous Devices for Disaster Mitigation

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At the time of a catastrophic calamity in which a telecom infrastructure receives a serious damage, the structure which shares information electronically and carries it simply by the help is useful. RFID (Radio Frequency IDentification Tag) which is one of the ubiquitous devices is a device which enables exchange of electronic data locally, and can be utilized as data storage in the information exchange at the time of a disaster. This paper describes the research-and-development result about disaster prevention application of RFID in the Disaster Management and Mitigation Group.

### *Keywords*

Radio Frequency IDentification, Ubiquitous, Disaster mitigation, Positioning, Cellular phone

### 1 Introduction

RFID, which has become a ubiquitous device, began its rapid spread at the start of the 21st century. This paper describes our research and development efforts concerning the application of RFID in disaster prevention since 2001. The results of our research and development up to FY2004 has already been reported in previous issues of the NICT Journal and elsewhere [1] [21], so this paper focuses on the results after FY2005 reported by the Disaster Management and Mitigation Group.

### 2 Overview of RFID

RFID is a device that incorporates wireless communication circuits and memory to enable contactless ID reading by radio wave or electromagnetic induction using a terminal, or reader. RFID is either passive, which also enables data to be written by using a terminal (writer), or active, which discontinuously transmits a fixed ID, as with a radio beacon.

Whereas active RFID requires a power source, passive RFID does not use a power source. A passive RFID enables data to be transmitted over several centimeters, while an active RFID enables data to be communicated over several meters. Compared to paper as recording media, passive RFID has the advantages of higher data storage density per area, the ability to read instantaneously, and ease in saving, storing, and reusing the read information as electronic data. Also, it can control the access rights of users, thereby restricting the disclosure of information to family or public safety personnel. These characteristics are regarded as useful in an information exchange device during a disaster.

### 3 Information sharing using RFID during a disaster

#### 3.1 Overview

In the event of a large-scale disaster, it is inevitable that communication is disrupted. After the Great Hanshin earthquake, paper

posters were widely used to transmit information in the disaster area. Safety and evacuation information as well as the results of inspections of the damaged buildings were written on posters and posted directly on building walls. Consequently, information about disaster area exists within the affected area, which makes the collection and sharing of information using computer servers difficult, especially in the event of a large-scale disaster where the communication infrastructure has been seriously damaged. For this reason, during the initial stages of disaster recovery, manually transporting information should be the only possible way. It is therefore beneficial to take measures to share the information that has been collected manually from the disaster area in an electronic format, which may help rescue and recovery operations.

Against this background, the authors developed information-sharing technologies using RFID. Typically, RFID is used as a device to store only an ID whose meaning is acquired (resolved) from a server on the network, which is accessed by a terminal. However, the authors aimed to use RFID as a means of data storage, such as a flash memory. Passive RFID can satisfy this need because it operates without a power source on the device. Passive RFID has the drawback that it is possible to read data over a short distance. To overcome this drawback, during the early stages of development in 2001, a high-powered desktop reader-writer was configured on a push car so that read-write operations could be done as much as possible when the reader-writer and RFID were separated by some distance. A reader-writer that was mounted on a push car proved to have insufficient mobility, so it was modified so that it could be carried on the user's back while retaining the same configuration. In addition, a low-powered portable reader-writer was also developed to increase mobility, even sacrificing the read-write distance. The low-powered reader-writer was designed to be compatible with the initial high-powered reader-writer, and both terminals used the same RFIDs [1] [2].

As development progressed for use in collection and sharing disaster information, we introduced in FY2006 a hybrid RFID, with a square configuration, measuring 12.5 centimeters on one side. This device included both a passive and active RFID. We used the "Intelli-tag" (2.45-GHz bandwidth) made by Intermec Technologies Corporation as the passive RFID, and the "Spider V" (300-MHz band) made by RF CODE Inc. as the active RFID. Figure 1 shows the hybrid RFID, and Fig. 2 shows the developed terminal (reader-writer). For this development, we assumed a user scenario where an investigator in the disaster area walks around carrying the terminal that detects a signal from the active RFID. Once the existence of the tag is detected, the investigator approaches the tag to read and write more detailed information using passive RFID. Figure 3 represents an investigator



**Fig.1** Hybrid RFID  
(left: passive RFID, right: active RFID)



**Fig.2** Hybrid RFID reader-writer  
(flat panel antenna is for passive RFID,  
diversity antenna is for active RFID)



**Fig.3** Usage of hybrid RFID reader-writer

holding the antenna over the passive RFID for read-write operation in a demonstration experiment.

During the initial stages of development, we assumed the following usage scenario: an RFID is installed as an electronic doorplate at the entrance of a building, and the residents of the building record safety and evacuation destination information as they evacuate the building. The reader-writer was made with functionality that enables user operation to be navigated by a synthesized voice, so that the device can be used by an operator who does not have so much technological expertise. The reader-writer was made with another feature that reads message content (double-byte character sequence) aloud in a synthesized voice while it is being read from or written to a passive RFID. This feature of a speech system using RFID alone was presented in various exhibitions by NICT Incubations as a unique application of RFID that can also be used as an audio guidance system, beyond the scope of disaster prevention applications. Since the message is written to the user area of the RFID as data, the terminal can convert it into speech as a stand-alone device, without having to access the network.

Based on these features, we extended our development to various technological applications as we engaged in research and development projects in the field of disaster prevention. These applications are described in the following sections of the paper.

### 3.2 Support for rescue operations using RFID<sup>[3]</sup>

In FY2002, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched the Special Project for Earthquake Disaster Mitigation in Urban Areas, which conducts research and development aimed at significantly reducing human injury and physical damage in the event of earthquake comparable to the Great Hanshin earthquake in urban area, such as Tokyo (southern Kanto) or the Keihanshin area. The project aimed at establishing a scientific and technological foundation for the prevention of disasters resulting from earthquakes. This was a large project comprising four major categories, such as optimization of the disaster response strategy, such as when rescuing disaster victims. The major categories each consisted of sixteen intermediate categories, such as development of the foundation for the next generation disaster prevention techniques, such as a rescue robot. One of the subordinate categories under this intermediate category was the development of an emergency information collection system using RFID. This subordinate category was assigned to NICT, for which we embarked on the study of information gathering and sharing via RFID.

In this project, we strived to apply RFID technologies to information sharing among members of the rescue team. As an example of shared information, we assumed rescue information concerning victims in collapsed buildings. More precisely, during a search and rescue operation for victims trapped inside collapsed buildings, the rescue member logs his or her operation in the RFID. The next rescue worker then reads this operation log left at the rescue site before preparing an operation plan. This procedure eliminates the duplication of unnecessary rescue steps, and provides information about the rescued victims, such as the extent of their injuries and the hospital to which they have been taken. In this case, the use of RFID instead of paper posters enables information access to be controlled, and thus personal information to be handled safely.

In addition to the above, application was assumed for an NBC (nuclear/biological/chemical) terrorist attack in a subway, where rescue robots are used to search for victims and to remove dangerous items. In this scenario, the results of the operation, such as a report on victims exposed to chemicals, is written to RFID and put at the entrance to the hot zone (dangerous area) so that the site information can be shared with a subsequent rescue team via RFID.

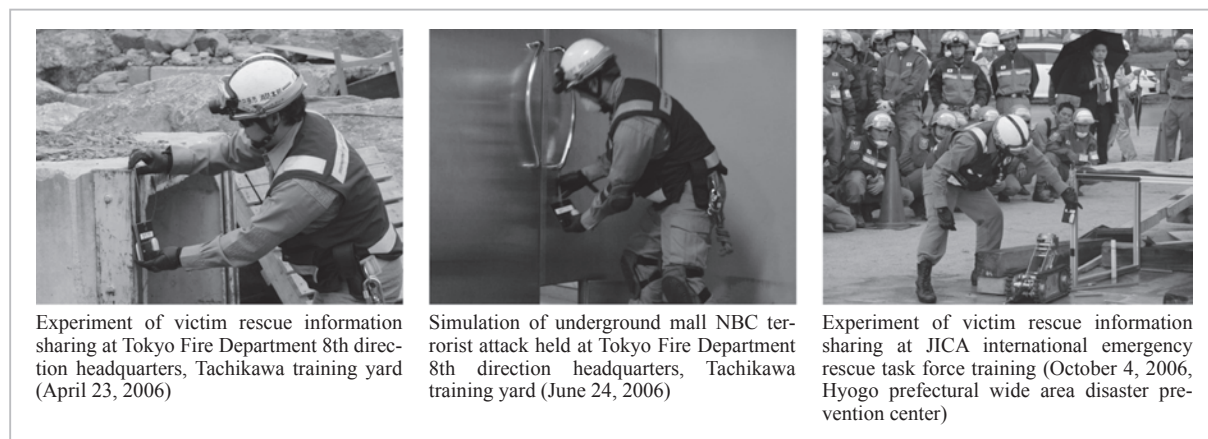
Figure 4 shows examples of usage in the rescue drills of various possible rescue operations where hybrid RFIDs are installed. Apart from these, similar demonstration experiments were conducted in Kawasaki Azelea (November 5th, 2006) in the underground mall of Kawasaki station in Kanagawa prefecture, and the collapsed house simulation facility (November 23, 2006) of the International Rescue System Institute Kobe Laboratory.

### 3.3 Support for investigating the extent of damage during a disaster<sup>[4] [19] [20]</sup>

In the event of a large-scale disaster, the rapid gathering of information is vital to a strategic rescue operation in understanding the extent of the damage and in enabling the adequate deployment of resources such as manpower. To gather highly reliable information, it is necessary for the investigator to go directly into the affected area and to move around, rather than waiting for information to arrive

from the area (In any case, it is likely that communication has been lost). Despite that, conducting such an investigation in a short period of time with while covering the entire disaster area is very difficult in a situation where manpower is usually insufficient, even for the emergency response. By convention, the only option in these circumstances was to rely on estimates and on the limited information gathered by a small number of personnel. To resolve this problem, it is necessary to have an investigation support system in the event of a large-scale disaster to ensure effective information gathering by a small number of personnel.

In a research and development project, entitled Disaster Mitigation Using Technology to Share Information for Risk Management (FY2004–2006), which was supported by the Special Coordination Funds for the promotion of science and technology, a GIS (Geographic Information System) was developed for site investigation of a disaster area. This system makes it possible to specify the location of the damaged area on a map, enter details of the damage at the target location, and store it in a terminal. The RFID reader-writer that we developed has a feature that enables writing messages (as double-byte character sequences) as well as a binary data file into the RFID, and to read the RFID data and save it as a file. By integrating these features, therefore, it becomes possible to write the results of investigating the extent of the damage to a passive



Experiment of victim rescue information sharing at Tokyo Fire Department 8th direction headquarters, Tachikawa training yard (April 23, 2006)

Simulation of underground mall NBC terrorist attack held at Tokyo Fire Department 8th direction headquarters, Tachikawa training yard (June 24, 2006)

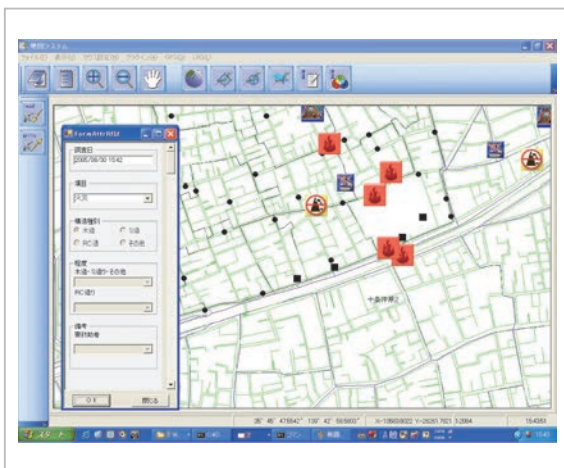
Experiment of victim rescue information sharing at JICA international emergency rescue task force training (October 4, 2006, Hyogo prefectural wide area disaster prevention center)

**Fig.4** Installation of hybrid RFID in various simulation training



RFID and to leave the information at the disaster site. Also, by using a passive RFID reader, it becomes possible to read the damage information that has already been written to the RFID. A passive RFID reader-writer is incorporated as a plug-in for the application that was designed for the on-site investigation of damage, so the reader-writer can be started from this application. As shown in Fig. 5, the data input window used in the RFID read-write operation appears on top of the on-site investigation application window.

To evaluate this application, we conducted an experiment to gather information on disaster damage, by incorporating the system in a disaster prevention drill performed on September 4, 2005, in 5 Chome Kami-Jujoy, Kita-ku, Tokyo Metropolitan Government. This experiment virtually assumed three fires, 15 building collapses and three road closures in a town occupying an area of 500 square meters. At each disaster site, signage with a passive RFID was installed. A participant in the experiment who carried an investigation terminal determined the extent of the damage (damage assessment result and the number of victims needing to be rescued) from information stated on the signage, and stored it in the RFID. Another participant then collected this information by reading from the RFID and consolidating the information at the disaster headquarters. The effectiveness of this process was compared to a case where a paper map was



**Fig.5** Screen for on-site investigation of disaster damage situation

used to gather information. Figure 6 represents the experiment. A black square at the right bottom of the signage is the passive RFID. In the experiment, the system could operate almost as intended by design, except for failures caused by user mistakes.

A similar experiment was conducted on November 20 in Toyohashi-shi, Aichi prefecture.

The results of these field experiments indicated that there was a need for the RFID to be easily found by investigators when it was put at the disaster site. To meet this requirement, we added a function for receiving an ID transmitted by an active RFID by using the hybrid RFID described earlier in this paper. Also, we designed the terminal to make a beep sound when it received an active RFID so that a rescuer could quickly find the RFID on-site. We also developed a feature to depict on the GIS the estimated distance from the terminal by measuring the field intensity of the active RFID. The distance was represented on the GIS as a circle centered on the terminal's own location positioned by GPS. Figure 7 is a screen shot of this enhanced GIS. This feature enabled rescuers to rapidly find the RFID locations during the investigation.

A similar experiment was conducted using this enhanced terminal on November 3, 2006, again in a disaster prevention drill at 5 Chome Kami-Jyujyo, Kita-ku, Tokyo Metropolitan Government. Figure 8 represents this experi-



**Fig.6** Experiment in disaster prevention drill at 5 chome Kami-Jujoy, Kita-ku Tokyo Metropolitan Government (September 4, 2005)

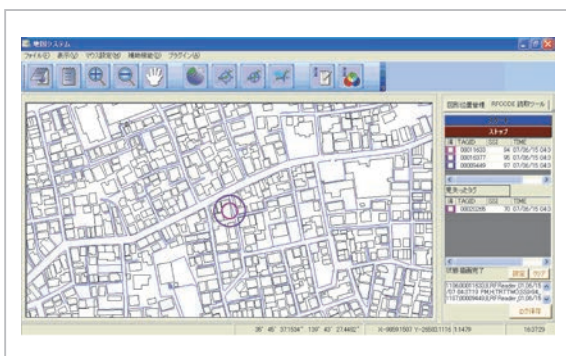
ment. In the image at the left, a hybrid RFID is attached to the right side of the signage with adhesive tape. With the new terminal, it was possible to detect the RFID fastened to the installed location as well as the RFID that the rescuer, who was moving around, hung around his neck (Fig. 8, right). This result confirmed that the effectiveness of RFID detection was improved as expected.

Development of the hybrid RFID system and the above experiment were reported at the System Integration Division Conference (SI2006) of the Society of Instrument and Control Engineers[5], and received the Presentation Excellence Award. Initially in this terminal, the active RFID was simply considered as a marker to notify rescuers of the existence of the passive RFID. Our next step was to equip the active RFID with a feature to transmit its absolute location information through the use of positioning by active RFID in places where GPS positioning was difficult.

Figure 9 is a screen shot of the application

with the feature for acquiring the terminal's position by using location information obtained from GPS or active RFID. When a GPS signal is received, the location of the terminal (latitude and longitude) is positioned by GPS and displayed at top right of the display window. When an active RFID is received, the terminal refers to a built-in location resolution table (MS Access format), converts the ID to latitude and longitude, then displays the location of the terminal (ID and its associated latitude and longitude) in the right center of the display window. Using active RFID as a source of latitude and longitude information enabled disaster investigation to become available while the investigator was aware of his terminal's absolute position, both in an outdoor location where a GPS signal could be received, as well in a closed space, such as underground mall, where GPS signal reception was poor.

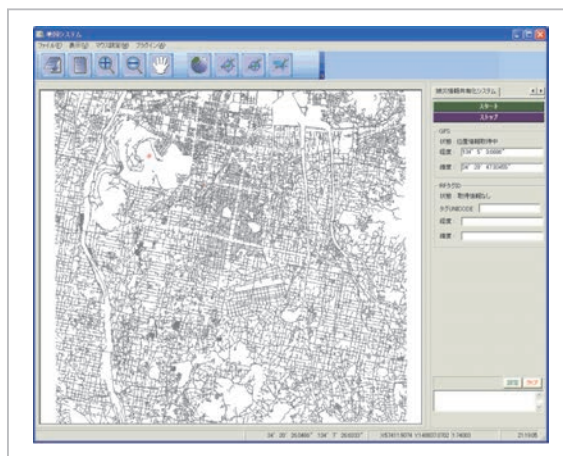
This application requires that a built-in location resolution table is stored before use so that the ID of the active RFID can be converted into latitude and longitude. The application was therefore not practical in the case of a site that had never been visited. The next enhancement enabled this location resolution table to be stored on the server (location resolution server) accessed via the Internet. The terminal was equipped with a mobile communication card, and the terminal was able to



**Fig.7** GIS screen enabled by feature to indicate estimated location of active RFID by a circle centered on terminal's own location



**Fig.8** Experiment in disaster prevention drill at 5 chome Kami-Jujo, Kita-ku Tokyo Metropolitan Government (September 3, 2006)



**Fig.9** GIS screen enabled by feature to indicate terminal's own location retrieved by GPS or active RFID

resolve its location by accessing the network. Figure 10 is a screen shot of the enhanced GIS. The result of GPS positioning or RFID positioning is shown in the right side of the display window. The RFID positioning result is shown as a set consisting of the following information: received ID, the latitude and longitude returned by the location resolution server to which the received ID is sent, the location name, the address and so on. In addition, the window below displays the URL that corresponds to the area where the received ID exists. When the user presses the Display Link URL button, a web browser starts and displays the content retrieved by this URL. If the IDs of multiple tags are received, the first received ID is processed and the second and subsequent IDs are ignored. The location resolution server described in this section is also used in Chapter 4, as the server used for cell phone positioning using RFID.

## 4 Cooperation of cell phone terminal and RFID

### 4.1 Overview

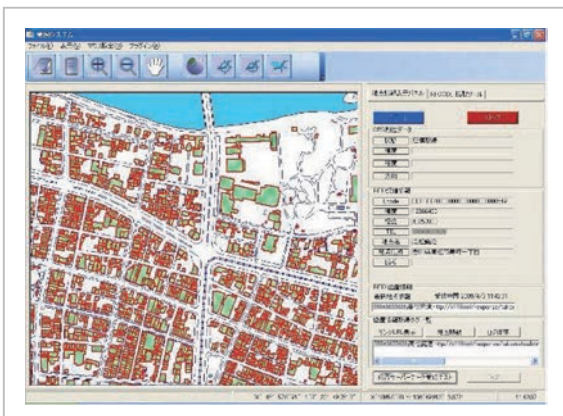
Cell phones are extensively used communication devices, so it is important to consider using it in combination with RFID. Cell phone terminals equipped with a built-in passive RFID are already in practical use as electronic money and as electronic tickets for use on public transport. In contrast, cell phone terminals that incorporate RFID readers are just

now becoming technically practical. KDDI Corporation created prototypes of two cell phones: one that has a built-in reader of active RFIDs and one that has a built-in reader of passive RFIDs[6]. NTT DoCoMo Inc. has been promoting research into reducing power consumption so that active RFID readers can be incorporated in cell phone terminals[7].

First, a means of connecting a cell phone terminal with a unrewritable (read-only) passive RFID reader as an external device became available[8]. This consisted of E03CA, an au cell phone terminal, and a 2.45-GHz bandwidth passive RFID reader (HE-MU380-SH11, Mu-Chip reader produced by Hitachi Ltd.), which was connected by an attachment (Fig. 11).

Furthermore, if the cell phone terminal is equipped with Bluetooth communication functionality, Bluetooth devices can be dealt with as a type of active RFID by using the device address as the ID. Therefore, the authors developed an application on a cell phone terminal that uses the small wireless acceleration sensor (WAA-001 produced by Wireless Technologies, Inc.) shown in Fig. 12 for its Bluetooth communication feature to be used as an active RFID.

Moreover, a small RFID reader-writer module with low power consumption intended for cell phones was developed through research under contract, entitled A Study on Ubiquitous Platform Technology[9] by the Ministry of Internal Affairs and Communica-



**Fig. 10** GIS screen enabled by access feature to location resolution server



**Fig. 11** Cell phone terminal equipped with passive RFID reader attachment (au E03CA)





**Fig. 12** Bluetooth device (small size wireless acceleration sensor) used instead of active RFID

tions. In FY2010, a cell phone terminal with embedded UHF band RFID reader-writer was developed (au E05SH)<sup>[10]</sup>.

In this section, we describe RFID positioning and information sharing that uses RFID as data storage that are enabled on the cell phone platform using devices developed above.

#### 4.2 Cell phone positioning using RFID<sup>[11]</sup>

Location information services that make use of satellite positioning technologies have come into widespread use, together with the extensive use of cellular devices such as cell phones. Nevertheless, problems have emerged, such as the existence of areas where location information cannot be obtained by GPS or where there is poor positioning accuracy. Therefore, a research and development project, entitled RFID-based Positioning Systems for Enhancing Safety and Sense of Security, was commenced in FY2006 and continued for three years with the support of the Special Coordination Funds for the promotion of science and technology. A characteristic of this project was the cross-ministry effort that was made, since the project belonged to the Coordination Program of Science and Technology Projects, which are being promoted through inter-ministry cooperation due to its national and social importance. The principal researcher was Associate Professor Kaoru

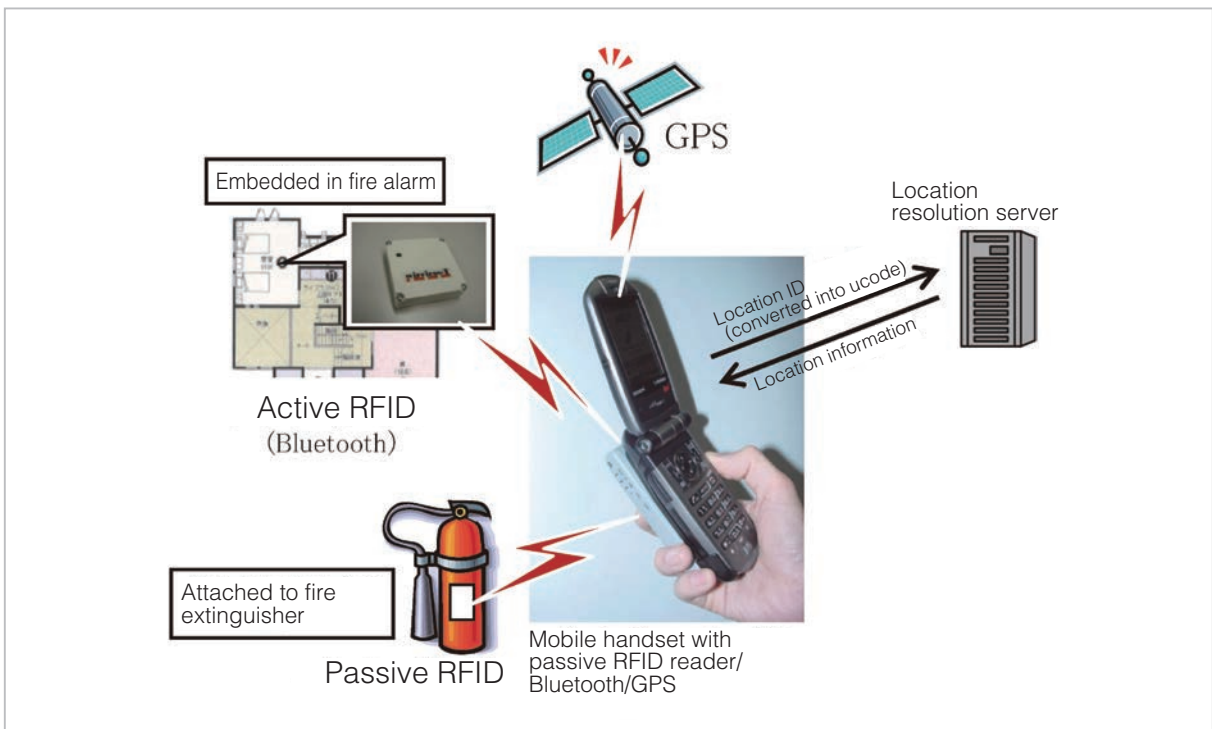
Sezaki from the Center for Spatial Information Science at the University of Tokyo. Participants were the Ministry of Land, Infrastructure, Transport and Tourism, the Geographical Survey Institute, the Ministry of Internal Affairs and Communications, the Fire and Disaster Management Agency (Fire Service Technology Policy Office and National Research Institute of Fire and Disaster), the National Police Agency, the National Research Institute of Police Science, and NICT.

Most location-aware technologies or traceability technologies realized by RFID are used in configurations where the RFID is attached to movable entities, such as people or materials, RFID receivers that are connected to a network are installed at fixed locations, and the location information is controlled by a server in a coordinated manner. Unlike these technologies, this project strived to achieve a unique system in which the RFID is installed as a location marker in an environment, while people carry the terminal that has RFID receiver functionality. This configuration has the benefit of low infrastructure costs.

RFID positioning is enabled by mobile terminals that receive the ID from an RFID installed in the environment. The location resolution server is accessed through the network and the location of the ID is queried and retrieved as the location of the terminal. This means that the positioning accuracy of the terminal's location depends on the reading distance of the ID. Also, it is prerequisite that the location information for ID is registered in the location resolution server.

Figure 13 shows the operation of the RFID positioning application we developed. The terminal shown in Fig. 11 in Section 4.1 is used. The terminal reads the passive RFID or Bluetooth device address and transmits the ID to the location resolution server. The server queries the location information that corresponds to the sent ID, and it returns the retrieved location information to the terminal. The location information is defined for each ID in the latitude and longitude conversion table stored on the server. The latitude and longitude, as well





**Fig. 13** Three-way positioning mobile handset

as the location address, are specified in an arbitrary format. Moreover, the server queries the area surrounding this location, and returns the URL that is specified for this area. This URL is sent back to the terminal together with the location information. The area and corresponding URL are defined by the polygon table stored on the server. If the terminal cannot receive the ID, it acquires the latitude and longitude by GPS positioning and transmits the acquired location information to the server. The location resolution server queries the location for the surrounding area to send back the URL defined for this area to the terminal.

This cell phone application is designed on the assumption of the following feature set: the cell phone terminal receives the ID transmitted by RFID that is embedded in a fire alarm set on the ceiling. When a rescue request is made from the room using this cell phone terminal, the application identifies the fire department in the jurisdiction to be contacted. The location information of the terminal is automatically reported to the caller location display system of the fire department [12]. In this case, the area defined by the polygon

table emulates the jurisdiction area of the fire department, and the URL defined for each area emulates the contact URL of this fire department.

Figure 14 shows an example of the latitude and longitude conversion table stored on the location resolution server. In the example, as the location of the RFID whose ID is 0eff fe40 0000 0000 0000 0005 49e9, the table defines 35° 42' 14" 92 north, 139° 29' 16" 53 east, location name National Institute of Information and Communications Technology, location address 4-2-1 Nukui-Kitamachi, Koganei-shi, Tokyo Metropolitan Government.

Figure 15 shows an example of the polygon table stored on the location resolution server. In the example, the area of 35° 42–43' NL and 139° 29–30' EL is defined by four points, and the contact URL of the fire department is listed, which can be identified as uniquely corresponding to the square region. Although the area is defined by four points in this example, it is possible to increase these coordinate points, and thus the polygonal border shape can be represented as it is in the

No.	Area	Address	北緯/東経 (度 分 秒 msec)			
006	〒114-0001	東京都小金井市豊井北町4-2-1	35	42	14	92

**Fig. 14** Example of latitude and longitude conversion table

ID	実地表示URL	消防署本部	電話番号
9	http://xxxxxxxx/response/kogane-fire-dept.html	小金井消防署	0423270000

点番	北緯			東経		
	度	分	秒	度	分	秒
1	35	42	00	139	29	00
2	35	42	00	139	30	00
3	35	43	00	139	30	00
4	35	43	00	139	29	00

**Fig. 15** Example of polygon table

actual map. If the area defined by the polygon table includes the ID location defined by the latitude and longitude conversion table, and the terminal receives this ID, the URL defined for this area is returned from the location resolution server. When the terminal accesses this URL, for example, the contact screen appears to enable connection to the fire department in this area.

Having a location resolution server on the network enables the RFID transmission data to be reduced to the ID only, thereby minimizing the required memory capacity. Location information can be uniformly managed by the server, which simplifies maintenance. However, location resolution becomes unavailable when a network failure occurs, such as in the event of a disaster.

### 4.3 Information sharing feature using an RFID as data storage<sup>[13]</sup>

Our objective was to achieve the information sharing feature as described in Chapter 3 on the cell phone platform as well. In normal times, it can serve to offer limited local infor-

mation, instead of conventional paper posters or message boards. For example, it can provide valuable information that can be exclusively accessed by people who visit a location. It can function as a guest book or as pilgrims' slips in tourist locations, such as temples and shrines, or as a stamp rally. In the event of a large-scale disaster when cell phone communication is lost, it is intended that information is exchanged via RFID, as described in Chapter 3.

Before the cell phone equipped with an RFID reader-writer in the UHF band was developed in FY2010, as described in Section 4.1, there was no available cell phone terminal that allowed data to be written directly to an RFID. Writing to an RFID was virtually realized by use of the cell phone terminal with a read-only passive RFID reader attachment, as shown in Fig. 11 in Section 4.1. Due to the read-only attribute, information that was read or written was designed to be stored as a message under the automatically created thread associated with the ID on a web-based BBS (Bulletin Board System). More simply, the passive RFID in the RFID application for positioning described in Section 4.2 was modified to specify the BBS thread in this feature, instead of being used for positioning. Therefore, a similar feature can be realized through the use of two-dimensional code, such as a QR code instead of RFID.

The procedure for writing information is as follows: When an ID is received from a passive RFID, the cell phone terminal transmits the ID to BBS. The input screen is then displayed to write the information. If a thread that corresponds to the ID already exists, the information input from the screen is written as a new message under the existing thread. If a corresponding thread does not exist, a new thread is created and the information input from the screen is written. If network access is not available when the data is written, an input screen appears to save message in the terminal. The stored messages are sent to the BBS when network access becomes available. In this manner, by virtually enabling the write operation while offline, we intended a user

experience that is closer to the real usage to directly write information to the device. The written information consisted of the following: the message that the user entered from the terminal, the time at which the message was written, location information acquired by the Bluetooth device or by GPS positioning, as described in Section 4.2, and auxiliary information received from the location resolution server.

The procedure for reading the information is as follows: Upon receipt of an ID from the passive RFID, the cell phone terminal accesses BBS, displays the thread that corresponds to the ID, and selects and displays the message written. If no network access is available, the read operation cannot be performed.

After a cell phone terminal with an embedded RFID reader-writer of the UHF-band was developed in FY2010<sup>[10]</sup>, we developed an application feature for writing messages to the actual RFID, not to the BBS. Figure 16 represents the operation.

In this application, a character sequence can be entered by using the numeric keys on cell phones so as to create a text mail message. The write operation is executed by holding a cell phone over the passive RFID (Mu-Chip Hibiki) with a 950-MHz bandwidth. Once the read operation is executed, the character sequence written in the user area of RFID is displayed on the screen. It is possible to select whether all or part of a message is read, and the part to be read is specified by the

starting byte of the selected message. Figure 17 shows the screen shot of the input display.

## 5 Development of generic RFID terminal

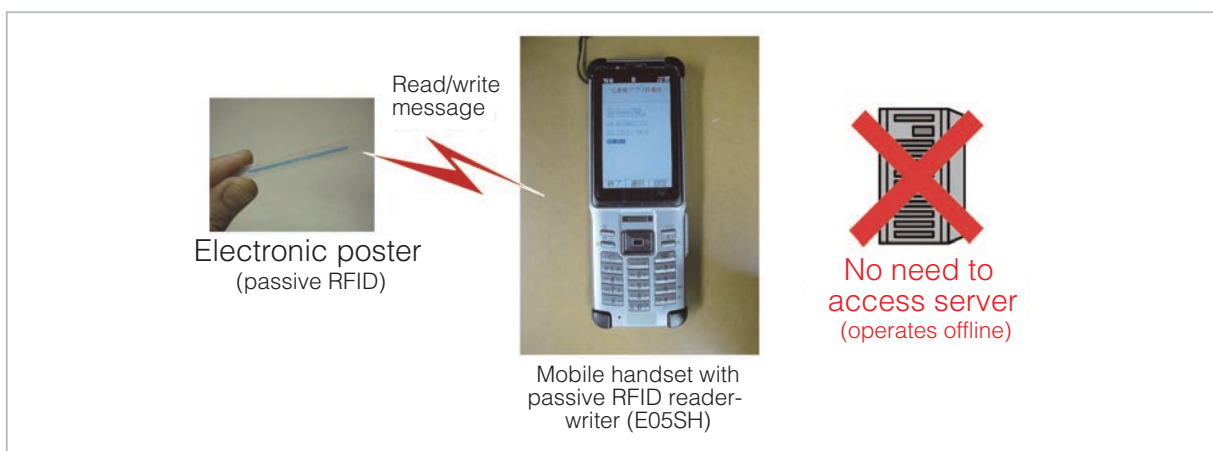
### 5.1 Overview<sup>[14]</sup>

Establishing compatibility is one of the challenges of an RFID system. Most conventional RFID systems were developed without assuming interoperability with other systems, and this is considered a reason for them not being in widespread use. In this section, we describe the generic RFID terminal developed under the project entitled RFID-based Positioning Systems for Enhancing Safety and Sense of Security.

### 5.2 Integrated reader-writer that supports multiple RFIDs<sup>[15]</sup>

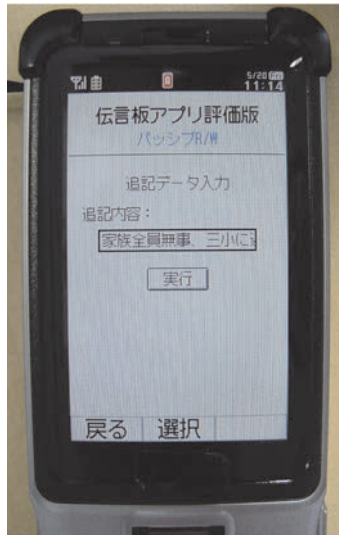
In the project, RFID-based Positioning Systems for Enhancing Safety and Sense of Security, six types of RFID were used, as shown in Table 1. In this paper, each RFID type is hereinafter represented by an identifier (RFID 1 through 6) shown in the right-most column of Table 1. We developed a prototype of an integrated reader-writer that supports multiple electronic tags, which enables all of these RFIDs to be read by a single portable terminal (Fig. 18). This device also has a feature for writing a Japanese character sequence to the user rewritable area of RFID 4.

This terminal was built based on the

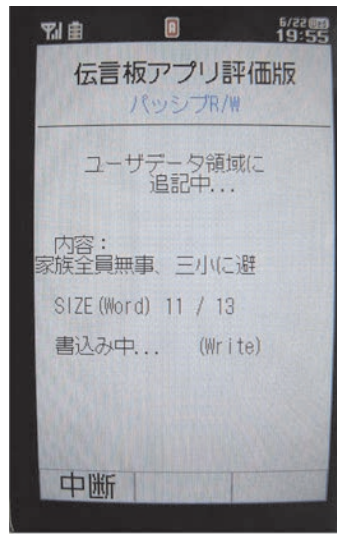


**Fig. 16** Operation image





Left: Input screen



Right: Screen when writing to RFID is in progress

**Fig. 17** Screens that appear during the write operation by mobile handset with UHF band RFID reader-writer.

**Table 1** RFID used in the project, RFID-based Positioning Systems for Enhancing Safety and Sense of Security

Organization	Purpose of RFID use	Specification of RFID	RFID manufacturer and model name	RFID shape	RFID type
Geographical Survey Institute	Intelligent reference point	13.56 MHz passive type (ISO/IEC 15693 compliant)	MB89R118 by Fujitsu Limited.		RFID 1
	RFID tape	300MHz band active type	TagStation model 310 by Kyushu Ten (power source is modified)		RFID 2
CSIS, the University of Tokyo	Location marker to improve positioning accuracy	300 MHz band active type	Spider V by RF Code		RFID 3
NICT	Beacon of Hybrid RFID				
	Electronic poster by use of Hybrid RFID	2.4GHz band passive type (ISO 18000-4 compliant) read-write access type	Intellitag RZ-1TG4 by Intermec		RFID 4
Fire and Disaster Management Agency	Self-location positioning to make emergency rescue request, location marker for integrated cell phone system	Bluetooth (equivalent to 2.5GHz band active type RFID)	WAA-001 3-Dimension acceleration sensor by Wireless Technologies Inc.		RFID 5
		300 MHz band active type	Engineering sample of KDDI Corporation		RFID 6



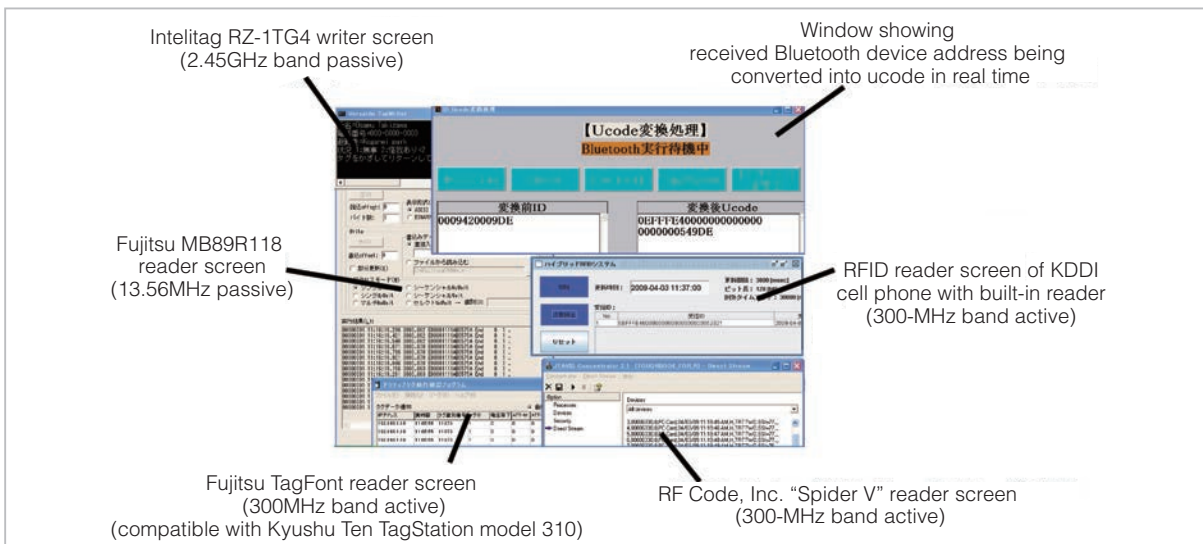
**Fig.18** Prototype of integrated reader-writer with support for multiple RFIDs

TOUGHBOOK CF-18 tablet PC produced by Panasonic. The main units of multiple RFID reader-writer devices, the antennas and supplementary batteries are placed in a box attached to the bottom of the PC. It has an interface that plots the location information retrieved from the location resolution server by way of a cell communication module. RFID 1 uses the white flat panel antenna incorporated in the reader that is connected to the PC via a USB interface. RFID 4 uses the black flat panel antenna connected to the reader device inserted in the PC card slot. The data is read by holding either of these antennas over the RFID. In the case of RFID 4, it is possible to write a character sequence that is input from the terminal, as an electronic poster or message board. The RFID 2 reader is connected to the PC by a wired LAN cable and stored in the chassis. The ID is received by diversity antennas projecting from the chassis. The RFID 3 reader is inserted in the PC card slot, for which diversity antennas are placed in the chassis. The RFID 6 reader has an internal antenna and is box shaped. It is attached to the chassis and connected to the PC via an RS-232C cable. The RFID 5 reader is an off-the-shelf Bluetooth communication module with a USB connection interface. It is connected to the USB hub attached to the chassis. Since the Bluetooth communication module only

receives Bluetooth the device address (48 bit) of RFID 5 to be used as an ID, the pairing process is omitted. A GPS receiver module having a USB connection is also connected to the same USB hub. Using the above configuration, the reception of GPS data and the read operation (read-write operation for RFID 4) for two types of passive RFID and four types of active RFID are performed simultaneously. This is achieved using two USB ports (one of which is connected to two ports via the USB hub), two PC card slots, one RS-232C port and one wired LAN port on the PC side. Figure 19 shows a screen capture when all six types of RFID are being read.

Although it is physically possible to read multiple types of RFID, each RFID transmits an ID in its own format. Therefore, they cannot be applied immediately to processing by the location resolution server. For this reason, the project RFID-based Positioning Systems for Enhancing Safety and Sense of Security received an assignment of a part of the ucode region (16-bit amount) from the Ubiquitous ID Center, one of the ID management organizations, and developed a tool to convert the ID of each different RFID type to ucode in this region. This initiative enables each ID to coexist without any overlap, and become compatible with other systems that conform to ucode.

The assigned ucode region was 16 bit, namely, 0eff fe40 0000 0000 0000 0005 xxxx with the last four digits (xxxx) being from 0000 to ffff. This region was divided into the classes shown in Table 2 in accordance with the number of buildings and possible allocation according to the partitioning of the buildings, on the assumption that RFID was mainly used for indoor positioning. Also, the number of each RFID type to be used in the demonstration experiment for the project was considered for this allocation. For example, RFID 2 was required to be put deep inside a building. Therefore, Indoor Location Class A, which allowed a larger number of partitions per building, was assigned. RFID 5 and the RFID 6 used for positioning in the event of a



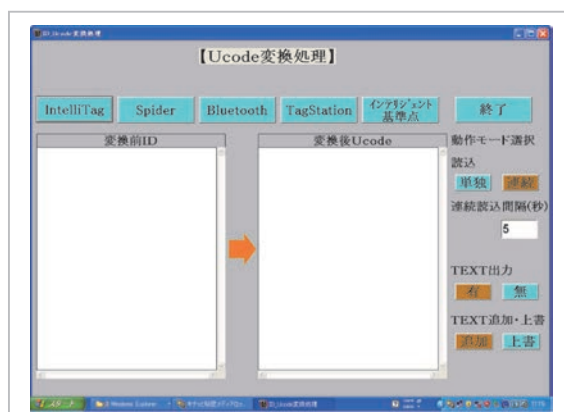
**Fig.19** Example of the screen for the simultaneous reading operation of six different types of RFID (top-left: RFID 4, middle left: RFID 1, bottom left: RFID 2, top right: RFID 5, middle right RFID 6, bottom right: RFID 3)

**Table 2** Last four digits of ucode assigned to the project, RFID-based Positioning Systems for Enhancing Safety and Sense of Security

	RFID type defined in Table 1	Bit value(Last four digits)														Region by hex representation of each bit value (Last four digits)				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16		
Indoor Class A	RFID 2, RFID 3	1	Outdoor locations (32 buildings)					Indoor locations (1024 partitioned areas)									8000~ffff			
Indoor Class B	RFID 5	0	1	Outdoor locations (64 buildings)					Indoor locations (256 partitioned areas)									4000~7fff		
Indoor Class C	RFID 6	0	0	1	Outdoor locations (256 buildings)					Indoor locations (32 partitioned areas)									2000~3fff	
Outdoor Class D1	RFID 1	0	0	0	1	Outdoor locations (4096 points)														1000~1fff
Outdoor Class D2	RFID 4	0	0	0	0	Outdoor locations (4096 points)														0000~0fff

rescue request could be arranged in a density of one per room. Therefore Indoor Location Class B and C, which had fewer partitions, were assigned. In addition, RFID 1 is assumed to be arranged in outdoor locations only.

Figure 20 shows the screen of conversion tool that converts the original ID of each RFID into the above ucode region. The original IDs of RFID 1 through 5 read by the reader devices are displayed in the left panel, and the converted ucodes are displayed in the right panel. During conversion, the ID that is read by each RFID reader is saved as a text file. The tool reads from the text file, converts the ID to ucode in compliance with the convention, and saves the data to another text file.



**Fig.20** Screen shot of ID conversion tool

Although the processing speed is restricted due to such text files mediating the input and output, it can easily absorb the differences in



processing specifications for each RFID reader. It also provides a simple way to pass control to processing after conversion to ucode. By design, RFID 6 allows any given ID setting. Therefore it was eliminated from the conversion processing as it was not necessary for the allocated ucodes to be set.

With this tool, multiple types of RFID are read, and each ID is converted to ucode and output as a text file. This design supports further processes, which can be called by entering the ucode. The processes can be executed by software. Therefore, this tool enables multiple types of RFID to be supported by a single piece of software.

A possible usage scenario for this terminal is as follows: when the user is walking in an outdoor location, the location information is acquired by using the terminal's GPS receiver. When the user finds RFID 1 on the street, he holds the terminal's antenna to determine the exact location information. When the user finds an electronic poster by RFID 3, he holds the antenna to read from or write to RFID 4. When the user enters a building where GPS positioning accuracy decreases, he acquires his location by using either RFID 5 or RFID 6, which has sufficient accuracy to identify the rooms. When he enters a room, he acquires the precise location by using the signal from RFID 2 placed at regular intervals, in which case the positioning accuracy is around one meter.

The integrated reader-writer that supports multiple RFIDs is certified by the Council for Science and Technology Policy as one of the technological elements comprising the ubiquitous network[16].

## 6 Social contribution of the results of development

In NICT, the research and development work for the application of RFID in the event of a disaster was concluded in FY2010. From now on, it is necessary to deploy the outcome of the development efforts so far for social benefit. For this purpose, we are preparing to

disclose all of our research and development results, including the applications described in this paper, together with the RFID reader-writers and associated devices, as part of the common-use facility program that starts from FY2011. These results and applications will be provided for a fee to external research and development organizations. Figure 21 shows the facility. This facility is called the Koganei RFID Workbench and planned to be serviced widely with RFID reader-writers and associated devices. The Koganei RFID Experimental Room[17], which was facilitated in FY2003 as one of the open laboratories, is equipped with these devices. Table 3 shows the list of RFID reader-writer devices that are expected to be serviced.

The Koganei RFID Experiment Room was used for exhibitions, such as Interlop. To assist in research and development for disaster prevention, experimental emergency exit lights have been installed. The laboratory was considered for use for the Development of an Information System to Support Fire-Fighting Activities promoted by the Ministry of Internal Affairs and Communications, the Fire and Disaster Management Agency[18].



**Fig.21** Koganei RFID Workbench

**Table 3** RFID reader-writer devices planned to be serviced in the Koganei RFID Workbench

Frequency (MHz)	Standard	Passive or Active	Manufacturer/ Reseller	Model Name	Remarks
13.56	ISO-15693	Passive	WELCAT	RHT-100-02	
			OMRON	V720S-HMF01	
			Feig	FPRH100	
				FMR100A	
Fujitsu	F3972T110				
300		Active	Hitachi ICS	ATRW-S01 (Engineering sample)	Compatible with sample mobile handset with built-in RFID reader (modified au W11H) [6]
			RF Code	Spider III Reader	Installation type
				Spider V Reader	Installation type
				Spider V Mobile Reader	Card type
Fujitsu	TFA-RW001				
950	ISO/IEC 18000-6	Passive	Fujitsu	F3977A3XX	
			Hitachi Corporation	HE-MU384-RWH002	High output power
				HE-MU384-RWH001	Embedded antenna
2450		Semi Passive	Alien Technologies/ TORAY International, Inc.	Nano Scanner B2450R01-A	
		Passive	Alien Technologies/ TORAY International, Inc.	Nano Scanner AL1201J	
			Intermec/Sharp	RZ-1TR2	Installed long-range type
				RX-1TR4	Installed long-range type
		RZ-1CD1		Card type	
		Standard	YSR-2400WLV		
		Hitachi Corporation	HE-MU380-SH11	External device of au E03CA	

It is planned that the mobile handset with embedded RFID reader-writer (au E05SH embedded type) the application for writing messages to the RFID described in Section 4.3, will be stored in the Koganei RFID Workbench.

## 7 Conclusion

In this paper, we described the application of RFID in the event of a large-scale disaster for electronic information exchange at the affected site. In the case of a large-scale disaster where communication cannot be maintained due to frequent power outages or the failures of base stations and relay stations, information should be accumulated on the

nodes, and transmitted when communication is restored. Otherwise, the functionality for transmitting such information manually should be provided. The idea of Disruption-Tolerant Networking (DTN) has been proposed based on the assumption of such functionality. The application of RFID in disaster response, as described in this paper, is based on the use of information being transmitted by people, which shares a common idea with

DTN. However, our application is limited to information exchange mediated by the RFID reader-writer, and thus the RFID is not used to accumulate information received from the network. Therefore, it is desirable that a new device enables the accumulation of information delivered by a network in normal times, and if the network fails, the accumulated information is retrieved using the RFID reader by way of non-contact reading.

A passive RFID, which does not require a power source for any operation, such as entering information, accumulating data, or outputting data, is disaster-resilient and inexpensive memory device that requires no maintenance and that can be used semi-permanently. In the future, if an RFID is buried anywhere in an urban landscape, including under wall tiles, it can be used as a reference point for positioning, and an invisible poster or message can be left anywhere. In this way, it can be used for various purposes either during normal times or in the event of a disaster.

Over the past ten years, we have been engaged in the application of RFIDs to disaster response. During this time, RFID technologies have made dramatic advances. Incorporating an RFID reader-writer into cell phones that are carried by a large population of users was essential in the progress to turn the RFID into an extensively used device, not limited to specific business purposes such as logistics. This progress was finally achieved this fiscal year through the project entitled Research and Development of Ubiquitous Platform Technology under the auspices of the Ministry of Internal Affairs and Communications. The application we developed is intended to be used by members of the public to store data, and preparations have just been completed to achieve this objective. Nevertheless, a number

of problems remain to be resolved before the technologies can be significantly distributed, and the RFID device itself should evolve. It is necessary to achieve, for example, faster read-write processing of RFID data and larger data storage.

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