Technology Reports

Demonstration Experiment on Information Services Using Active RFID Reader Attached to Mobile Terminals

A prototype of information system using active RFID tags and readers attached to mobile terminals was developed. Based on this system, a demonstration experiment was conducted on "Mimamoru Service" and "Treasure Hunting Game" and its potential service application was confirmed.

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1. Introduction

Technologies used to monitor objects, alert, and even detect objects existing in real life and link them to information are being incorporated into mobile terminals. Among the object monitoring technologies is "ANSHIN-KEY Lock" of P903i, although its function is limited to locking the mobile terminal. Technologies for detecting objects and linking them to information include two-dimensional codes and FeliCa®*1. These technologies allow users to actively acquire information on a network by bringing their mobile terminals near the source of information.

Active Radio Frequency IDentification (RFID) is one of the technologies used to realize service that monitors objects, and service that acquires object-linked information without the user having to do anything consciously, even if there is a certain distance between the mobile terminal and the object. RFID involves the use of a tag that transmits an ID and a reader that reads the ID. Active RFID is a type of RFID where a battery is mounted inside the tag device to operate the RF circuit. However, there are no mobile terminals with a built-in active RFID reader and no cases where a combination of both services has been verified in the real world.

An active RFID tag and reader that can be attached to mobile terminals was manufactured experimentally using the technology referred to in Ref. [1], and an information system using the tag and reader was developed on a trial basis. The system adopts a function to monitor objects for determining the presence of a tag having a predetermined ID near the reader, and then utilizes a function to receive the tag ID in order to acquire information associated with the objects. The system is characterized by its ability to provide both functions simultaneously.

This article explains the overview of the system, describes "Mimamoru Service (service to prevent children from getting lost)" and the "Treasure Hunting Game" that utilize the two functions above, and summarizes the results of a demonstration experiment conducted on these two services.

2. Information System Overview

The functions available in the system and the system configuration that realizes these functions are explained below.

2.1 Available Functions

The system functions required for providing the services are described below.

1) Specific Tag Monitoring Function

With the tag's ID specified in advance, the reader uses this function to monitor the tag's ID and thereby monitors ("out" monitoring) whether the tag is nearby, and if not, alerts the mobile terminal. Tags used for this function are referred to as "specific tags" and are applied to object monitoring services.

2) Arbitrary Tag Detecting Function

This function allows the mobile terminal to access an external server, browse

*1 **FeliCa®**: A non-contact IC card technology developed by Sony Corp. A registered trademark of Sony Corp.

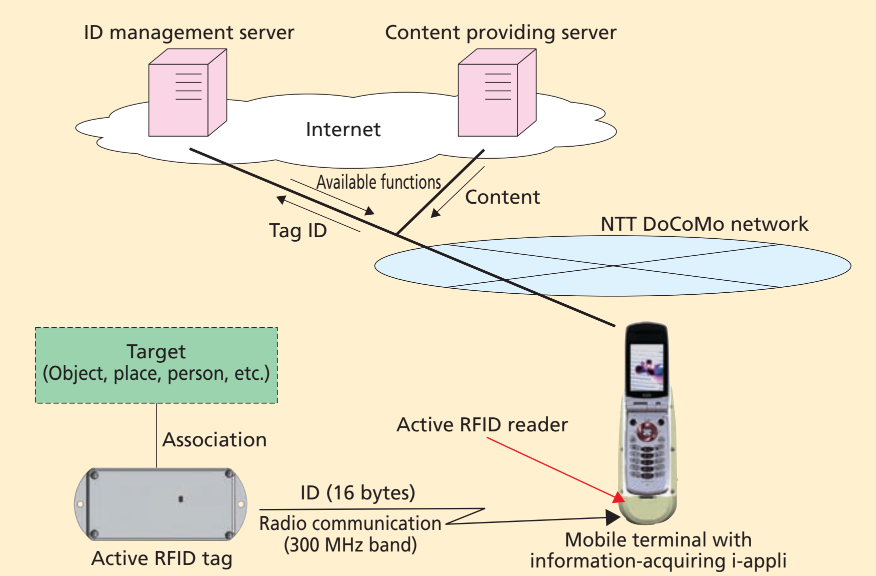

Figure 1 System configuration

Table 1 Basic specifications of the tag/reader

[Tag]

Size (mm)	90 (D) × 45 (W) × 10 (H)
Weight	Approx. 60 g
Continuous operation time	Approx. 4 weeks (assuming transmission at one-second intervals)
Range	Approx. 5 ~ 6 m
Frequency	300 MHz band

[Reader]

Size (mm)	150 (D) × 55 (W) × 16 (H)
Weight	Approx. 80 g
Continuous operation time	Approx. 12 hours
Attachable mobile terminal	N902i

content, activate ring tones, and take other such actions when an unspecified tag ID is newly received ("into" monitoring). The tags used in this function are referred to as "arbitrary tags" and are applied to object-linked information acquisition services.

2.2 System Configuration

Figure 1 shows the configuration of this system.

1) Active RFID Tag and Reader

Table 1 shows the basic specifications of the tag and reader. The system uses tags at two different frequencies depending on the function, and the reader switches between reception frequencies according to a specific tag reception time and arbitrary tag reception time.

The tag and reader utilizes the technology referred to in Ref. [1], while the antenna is based on the following:

a) Since the tags are carried around by people and placed on walls, the tags adopt a compact, low-gain, omnidirectional loop antenna that is not susceptible to the effects of arrangement materials. The tags are extremely low power radio stations compliant with item ⅰ, Article 4 of the Radio Law, so the gain of the compact loop antenna is sufficient.

b) Since non-reception may continually occur due to a lack of movement on the part of the user and very few changes in the propagation channel, transmission diversity is applied to the tag's antennas, which involves alternately switching between two antennas placed so that their plane of polarization[*2] is different.

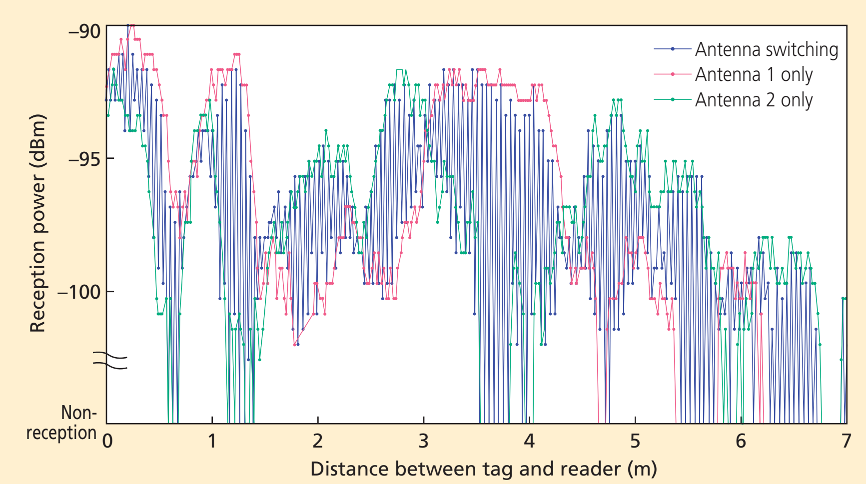

Figure 2 Reader's reception power characteristics relative to distance between tag and reader

*2 **Plane of polarization**: A plane determined by the direction in which magnetic waves propagate and direction of the electric field.

Figure 2 shows the reader's reception power characteristics relative to changing distance between the tag and reader to illustrate the effects of transmission diversity. This figure specifically shows the results of measurements in three scenarios while moving at low speed with the tag placed on the wall of a corridor about 2.5-meters wide. In two scenarios, only one of the tag's two transmission antennas was applied, and in the third scenario transmission diversity was applied. In cases of only applying one of the tag's transmission antennas, reception power is clearly low in some places due to multipaths. If the user remains in such places, the incidence of continuous non-reception of ID increases and the specific tag monitoring function is prone to erroneously notifying the user that the tag is not there, even if it is located nearby. Conversely, in the case of applying transmission diversity, the incidence of low reception power of transmitting the ID alternately from both antennas decreases; therefore, the incidence of continuous non-reception of ID can be kept low.

c) The reader's antennas are similarly configured as monopole antennas with a focus on gain, and its characteristics are adjusted while attached to a mobile terminal held in a hand.

2) Server

There are two types of servers: the ID management server and content providing server. The ID management server, which is a database, stores the information shown in **Table 2** and provides it to the information-acquiring i-appli. The ID management server is essential to this system. In contrast, the content providing server stores content and has a function to provide that content to mobile terminals. This server is constructed according to the service provided.

3) Information-acquiring i-appli

The information-acquiring i-appli refers to an i-appli that runs on a mobile terminal with a reader attached, and realizes the two available functions described in Section 2.1. The association between the tag ID and available functions is established by referring to Table 2 (3) from among the information stored on the ID management server as described in 2) above.

3. Demonstration Experiment on Service Application

This chapter describes the services provided by using the two functions of the system and summarizes the results of a demonstration experiment conducted on two services.

3.1 Description of Services

The following two services were simultaneously provided based on the system to a total of 366 families with children (up to 25 families per occasion) twice a day for a period of five days at two shopping centers from late July 2006 to early August 2006.

1) Mimamoru Service

This service is intended to prevent children from getting lost by using a tag and a reader attached to a mobile terminal. When a child holding a tag moves away from the parent beyond the tag's radio wave range, the mobile terminal with the reader attached uses the specific tag monitoring function to raise an alarm in 5 to 10 seconds to prevent the child from getting lost.

2) Treasure Hunting Game

This is an event-type service where a child and parent work as a team. Participants hold a mobile terminal with a reader attached and look for "treasure" hidden at five locations within the shopping center. Tags are placed near each treasure. By using the arbitrary tag detection function, the reader sends a message to the mobile terminal upon entering the tag's area to inform participants that they are near the treasure.

3.2 Experiment Results

The results of the demonstration

Table 2 Key information stored on ID management server

Item No.	Item	Description
(1)	Tag ID	ID uniquely assigned to tag
(2)	Tag ID reception intensity threshold	Threshold of tag radio field intensity at which tag ID is deemed detected by reader
(3)	Association between tag ID and function	Association with specific tag monitoring function/arbitrary tag detection function upon receiving tag ID
(4)	"Out/into" threshold	Number of times of continuous non-reception of tag ID during "out" monitoring/ Number of times of continuous reception of tag ID during "into" monitoring
(5)	Average tag ID transmission interval	Specified in increments of 1/16 of a second with respect to each specific tag/arbitrary tag
(6)	Specific tag/arbitrary tag reception time	Specified in increments of 1/16 of a second with respect to each one

experiment are summarized below.

1) Determination of Parameters

When simultaneously providing the two services described above, it is necessary to adjust the parameters concerning the average tag-ID transmission interval, the time for the reader to receive arbitrary tag IDs and specific tag IDs, and the "into/out" thresholds among the information shown in Table 2. In particular, the reader assumes the sum of the arbitrary tag reception time and specific tag reception time as constituting one cycle, and both services are provided simultaneously by repeating this cycle; consequently, the length of the arbitrary tag reception time and specific tag reception time affects the response time of the two services.

a) Parameters for Mimamoru Service

The procedure for determining the parameters involves setting the respective expected values of the average ID transmission interval for specific tags, the specific tag reception time, and the "out" threshold subject to the response time conditions, working out the theoretically calculated value of response time, and then confirming on-site the alarm-raising status.

There is a tradeoff whereby shortening the average ID transmission interval for specific tags reduces the response time, but at the expense of shortened continuous operation time of tags. Subject to the response time conditions, the expected values were set at 0.5 second, 1 second, and 1.5 seconds.

There is also a tradeoff whereby increasing the specific tag reception time for readers reduces the rate of tag non-reception, but at the expense of longer response time. Moreover, it was known in advance that a low rate of tag non-reception results when adding 3/16 of a second to at least double the average ID transmission interval (of 0.5 second). Therefore, the expected value was set at double or quadruple the average ID transmission interval plus 3/16 of a second (= 0.1875), that is, 1.1875 or 2.1875 seconds.

For the "out" threshold, a small value is preferred to minimize response time, but the rate of tag non-reception increases when this value is too small. Therefore, the expected value was set at 1 to 5 times.

Table 3 shows the theoretically calculated values of response time based on the aforementioned expected values, assuming an average ID transmission interval of 0.5 second. The yellow section indicates where the theoretically calculated response time is between 5 and 10 seconds; the light blue section indicates when it is outside that range. For example, if the specific tag reception time is 1.1875 seconds and the "out" threshold is once, the theoretically calculated response takes place at 1.625 seconds, which is equal to 1.1875 seconds plus the arbitrary tag reception time referred to in b) below (0.4375 second). If the "out" threshold is twice, response takes place at double the time (3.25 seconds) compared to when the "out" threshold is once.

During on-site confirmation, the expected value corresponding to the light blue section in Table 3 was excluded from the scope of confirmation due to assumptions different from those referred to in Section 3.1 1). If the specific tag reception time is 1.1875 seconds and the "out" threshold is four or five times, the theoretically calculated response time is between 5 and 10 seconds. However, the actual response time turned out to be more than 10 seconds during on-site confirmation, so the decision was made not to select those values as parameters to be provided. Moreover, in cases where the specific tag reception time was 2.1875 seconds and the "out" threshold was twice, alarms were frequently raised during on-site confirmation, so again the decision was made

Table 3 Theoretically calculated values of response time in Mimamoru Service

		Out threshold (number of times)				
		1	2	Adopted out threshold 3	4	5
Specific tag (Mimamoru Service tag) reception time	1.1875 seconds	1.625 seconds (0.4375 + 1.1875)	3.25 seconds	4.875 seconds	Response time exceeded 10 seconds in actual measurement: 6.5 seconds	8.125 seconds
	2.1875 seconds (Adopted specific tag reception time)	2.625 seconds (0.4375 + 2.1875)	Alarms were frequently raised during actual measurement: 5.25 seconds	7.875 seconds (Service content was also fulfilled in actual measurement)	10.5 seconds	13.125 seconds

Theoretically calculated response time was between 5 and 10 seconds (yellow)

Theoretically calculated response time was less than 5 or more than 10 seconds (light blue) not to adopt those values as parameters to be provided.

By assuming an average ID transmission interval of 0.5 second, a specific tag reception time of 2.1875 seconds and an "out" threshold of 3 times were accordingly selected as parameters to be provided.

Regarding the remaining expected value of the average ID transmission interval for specific tags at 1 second and 1.5 seconds, alarms were frequently raised during on-site confirmation even when the theoretically calculated response took place between 5 and 10 seconds. Therefore, the decision was made not to adopt these values as parameters to be provided.

Based on the above discussion, the parameters determined were an average ID transmission interval of 0.5 second, a specific tag reception time of 2.1875 seconds, and an "out" threshold of 3 times.

b) Parameters for the Treasure Hunting Game

The average ID transmission interval for arbitrary tags was set at 3/16 of a second (=0.1875) based on continuous operation time according to the specifications (in Table 1) and subject to two conditions: the tag must continually operate for five days since it cannot be removed and recharged once it is placed until the implementation period elapses due to restrictions at the location where it has been placed; and the tag must transmit its ID in the shortest cycle possible so that it can respond as soon as the reader enters the area.

The reader's arbitrary tag reception time was set at 0.4375 second, since it had already been known that a low rate of tag non-reception results when adding 1/16 of a second (=0.0625) to double the average ID transmission interval (0.1875 second) in this system.

The "into" threshold was set to once, due to the need for an immediate response in the Treasure Hunting Game.

2) Service Provision Results

Findings obtained from a questionnaire survey revealed that 59% of respondents experienced Mimamoru Service simultaneously with their participation in the Treasure Hunting Game. The remaining 41% of respondents were divided into two groups: one group that encountered no raised alarms since the participating parent and child were always close to each other, and another group that failed to experience Mimamoru Service due to the user interface. The findings from the latter group revealed that one future challenge lies in making the user interface a user-friendlier one when running the two services in parallel with each other. Participants who stated that Mimamoru Service is useful (including those who responded that it is of "average" usefulness) accounted for 79% of all participants. On the other hand, participants who stated that the Treasure Hunting Game was useful (including those who responded that it is of "average" usefulness) accounted for 87% of all participants. Based on this information, both services were deemed effective in terms of user satisfaction.

4. Conclusion

This article explained the overview of an information system using an active RFID tag and reader, and described a demonstration experiment conducted on two services. It also confirmed the potential of the system's service applications through the demonstration experiment conducted on Mimamoru Service and the Treasure Hunting Game.

The arbitrary tag detecting function and specific tag monitoring function were both deemed applicable to many fields. Our future challenge is to confirm such applicability subject to various requirements in order for application to a wider range of services.

REFERENCES

[1] S. Ohkubo et.al: "Technologies to Reduce Power Consumption of Active RFID Readers," NTT DoCoMo Technical Journal, Vol.8, No.1, pp.33-40, Jun. 2006.