Error Detection for the Reliable Digitally Named World with RFID Tags

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Error Detection for the Reliable Digitally Named World with RFID Tags

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Abstract

In this paper, we address reliability issues in the 'Digitally Named World', which is the environment in which RFID(Radio Frequency IDentification) Tags are attached to any objects in the real world, can be found by the RFID readers connected to the networked database system. Digitally Named World is launching into the real world, such as product sales management in retail stores, supply chains, product distributions, and production processes. Reliability is one of the crucial issues in the Digitally Named World, because of the unreliable nature of RF communication and human interventions to the operations. We propose the FRED (Fundamental system for REliable Digital naming), which improves the reliability and persists the consistency of the Digitally Named World, exploitting simple model of the behavior of the target objects and networked readers.

1 Introduction

Recent years' advances in information technology and system LSI technology are penetrating computing resources into ubiquitous places in the real world[8]. Mobile phones, which are equipped with advanced multimedia processing and program execution are an example of the world.

This trend can be considered that, so to say, the impact of the information technology is moving from 'The virtual world realized in computers' to 'the real world where computers reside pervasively'. In such an environment, the total system reliability is a crucial issue, since the problem in information systems directly results in the problem in the real world. 'What we should ensure by pervasive computing' is important as well as 'What we can do by pervasive computing' for fundamental infrastructure of the pervasively computable world.

Our vision of the future world is the *Digitally Named World[3]*, which is the environment in which 'radio frequency ID tags' (*RFID tags*) are attached to any goods in the world, they can be found anytime via the readers of the RFIDs and the networked database system, and they can be managed throughout their life-cycle. RFID tags are silicon chips with their IDs, radio frequency functions and some additional logic and memory[1, 13]. Most of the RFID tags are supplied with power through radio frequency communication from external readers. The Digitally Named World is launching into the real world such as the product management system, distribution companies, and retail stores.

In this paper, we propose a method for improving the reliability in the Digitally Named World. In the Digitally Named World, the information in the real world is captured and transferred to the virtual world. Here, if unreliable capure or transfer occur, the effect of the Digitally Named World becomes small, none, or even worse.

For the problem of reliability, we illustrate the example application in the supermarket in Figure 1. In the example, RFID tags attached to each product enable automatic calculation of buying products at a cacher which equips RFID reader.

However, since RFID is based on RF technology, there naturally exist unreliable communication caused by the range between the reader and the tag, or by an interference by obstacles[7]. If a product fails to be identified at the casher, the product will be took out without paying, where the recovery of the failure will be extremely high. Moreover, a customer might intentionaly avoids the identification, that is

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he/she attempts to steal. Thus, a failure of identifications and intentional avoidance reduce or vanish the merit of the Digitally Named World.

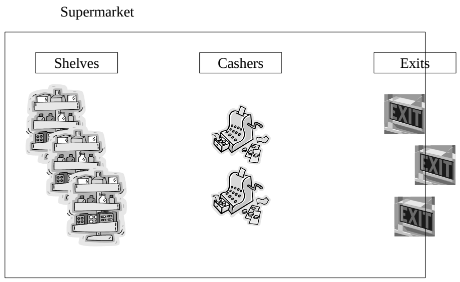

Figure 1: Supermarket example

For the reliability issue shown above, systematic approach is important as well as individual improvement on each reader and each tag. Even if there is a failure of an identification or intentional avoidance of an identification, the total system reliability can be preserved if the system surely detects the exceptions and recovers them. We propose a method for improving reliability and eventually preserving the consistency in the Digitally Named World by exploitting simple model of the behavior of the target objects and networked readers.

In the rest of the paper, Section 2 describes the basic features of RFID tags, Section 3 addresses the reliability in the Digitally Named World, and Section 4 describes the method we propose for improving reliability in the Digitally Named World. Section 5 is a conclusion.

2 RFID Systems

RFID tags (or simply a *tag*) are silicon chips with their IDs, radio frequecy functions and some additional logic and memory. In this section, we briefly describe the basic features and applications of RFID tags, which enables the Digitally Named World.

2.1 Basic features

Figure 2 is the basic architecture of an RFID tag. It has usually no battery, and the power and the clock are supplied via external radio frequency communication. The RFID tag computes with the power and the clock, and sends the result via radio frequency communication. We call the device which communicates with the RFID tag supplying the power and the clock an *RFID reader* (or simply a *reader*). An RFID tag consists of an RF circuit which manipulates wireless communication, logic circuit which processes small steps of computation, and memories such as a read only memory (ROM) or an electrically erasable read only memory (EEPROM).

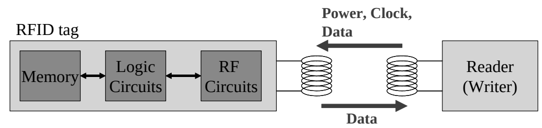

Figure 2: An RFID tag and a reader

As illustrated in Figure 3, an RFID System is a system for supporting the Digitally Named World, which consists of RFID tags and readers[11].

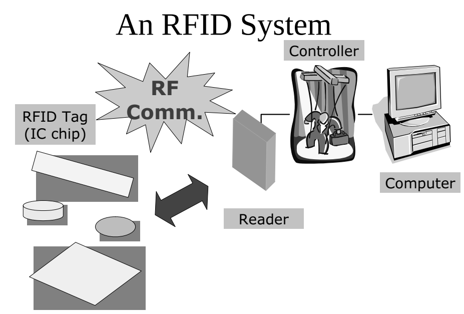

Figure 3: An RFID System

The memory is currently up to around 64kilobytes. RFID tags are implemented in many shapes such as an IC card, a key ring, and a seal. There exist RFID tags each of whose dimension except the antenna is under 1mm each. [16].

The communication time between a reader and an RFID tag is around 0.5 second, and the maximum communication distance is about 5 meters.

2.2 RFID Applications

RFID tags are mainly used for effectively managing massive objects by setting identification code to the memory of each RFID tag and attach it to each object.

In libraries, large amount of books can be easily searched by attaching RFID tags to the books.

Here, the reader is networked, and located on each bookshelf. The advantage of the system is that the users can search the location of the books without the books are arranged in order.

Airports are attempting to make baggage distribution effective, attaching RFID tags to baggages and incorporating with the baggage management system. This reduces the cost of distributing baggages, supports tracing lost baggadges, and improves the security in the airport. Currently, baggages in airports are attached barcodes tags and used for automating baggage distribution. However, the barcode system is unreliable, in which the rate of successful identification is around 70 percent, since the size and form of tags differs, tags are not attached uniformly in the particular place of the baggages, and tags offten break or become dirty. Using RFID tags, these weakpoints can be overcame, since they use RF communications which can use non-contact relatively long range communication. The RFID baggage distribution experiment in Narita airport reports the rate of successful identification was over 99 percent[12]. Moreover, RFID system can exploit the rewritable memories to check if the contents of baggage have been stolen, recording the initial weight of the baggage to the memories on the RFID tags.

In supermarkets and clothing stores, effective sale and cost reduction are attempted by attaching RFID tags to goods and connecting readers to the POS (point of sale) system. For production and distribution stages of an object, attaching RFID tags to parts or products accelerate the performance of the production or the distribution system. These applications profit the property that RFID tags manipulates non-contacted communication. For example, the total prices of many goods can be instantly calculated without approaching the reader as the bar-code systems.

RFID applications are certain to be widely spread, since the application area lies in any domains related to real objects. Many applications are engaged in many fields such as non-contacted transportation tickets[15], anti-stealing car keys, and domestic animal identification.

3 Reliability of the RFID Application Systems

As shown shown in Section 2.2, the Digitally Named World is launching into the real world, such as the product management system using RFID tags. In the stage of deploying the Digitally Named World, reliability becomes the crucial issues, because of the unreliable nature of RF communication and human interventions to the operations. Especially, there exists an inaccurate conversion between the real world and the virtual world which models the real world through RFID readers. Error detection and correction of the inaccurate conversion becomes more important as the Digitally Named World is deployed to critical domains.

Here, we clarify the reliability problem and address several viewpoints that can be exploit to solve the problem. As far as the Digitally Named World relies on RF technology which resides in the real world as physical phenomena, the following problems occur:

- An RFID tag fails to be identified by a reader, because of either the length between the tags and the reader, the placement and the direction of the tag, the moving speed of the tag or the reader, or the collision with nother RF devices including RFID tags or RFID readers. In the supermarket example, several products attached with RFID tags unidentified in a basket result in inaccurate incorporation of real world's events to the sales management system, and leads to inconsistency in the virtual world itself, such as a total sales miscalculation, or a lack of the total amount.

- A human user can either intentionally or unintentionally make tags unidentified, by means of the failures shown in the previous item. Stealing a product means an intentional misidentification, in which a customer displaces the product out of the communication area of the reader at a cacher, such that he/she exits skipping the cacher, or hide the product into a bag with an electromagnetic shield.

These problems originate from the nature of RF, but can be considered as a reliability problem of the Digitally Named World, since the problems cannot be solved by RF technology itself. Systematic approaches which can be applied to the fundamental system support mechanism (such as in a middleware) is important.

To establish the reliability of the Digitally Named World, we focus on the realtime detection of the reliability recession, which is a mechanism to detect the events which affects the reliability as soon as possible, such as an identification error of an RFID tag, and an intentional skipping of an identification. The mechanism will be a first step to maintain the reliability of the Digitally Named World, followed by the similarly important method to recover the reliability and the policy of the recovery. Moreover, realtime detection is highly effective, since the transactions in the real world are basically impossible to be rolled back, as stolen products cannot be mostly recaptured.

Our approach to maintain the reliability of the Digitally Named World is based on the folloiwing viewpoints:

1. **Accompany Constraint**: multiple objects in the real world are sometimes treated as a group, that is, moves together, such as multiple products in a market basket. If the system knows the composition of such groups, the system can infer the existence of the all elements of a group, only by identifying one or more element of the group, such as all the products in the basket can be assumed to be identified when only one product is identified by a reader, even if several products could not be identifed directly.

2. **Route Constraint**: an object in the real world is sometimes designated a specific or several possible routes to move. For example, products are routed on belt conveyers in a distribution center, and the products in the supermarket must checked at the cacher before the exit with the customer, followed by a wandering phase in the basket around shelves. These routes of the objects can be made use of by the system to detect errors in the Digitally Named World, since an invalid route log obtained by the RFID readers can be considered as an error, such that an exit event without the payment at the cacher is either a misidentification at the cacher or a theft.

Note that our approach is based on the incorporation and utilization of some real world constraints into the reasonable and feasible constraints in the virtual world. These approach can be / should be generalized to incorporate more effective constraints in the real world, such as total weights, visual information, sensor data.

In the following, we describe the fundamental middleware system for realizing our approach.

4 FRED : Fundamental system for Reliable Digital Naming

In this section, we present the FRED (Fundamental system for REliable Digital naming), which we are developing to improve the reliability and maintain the consistency of the Digitally Named World, including the approach shown in Section 3.

4.1 The system architecture and the data model

As in Figure 4, we assume the following components as the basic architecture of the system for the Digitally Named World: RFID readers connected to the networks, and the server(s) which provides services supported by the feasible model of the real world. Here, the feasible model of the real world consists of: 1. the application model as a products database, a customer database, and transaction protocols, and 2. the constraint models, some of which we introduced in Section 3. The following describe the detail of the constraints model which we adopted.

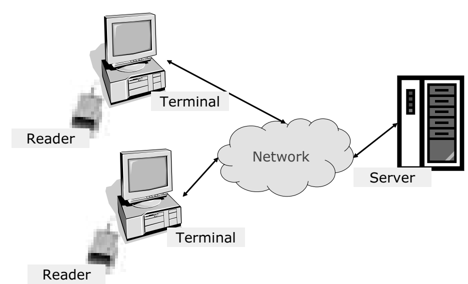

Figure 4: The basic architecture of the FRED

- The server restores the following directed graph before the initial execution as an Route Constraint : each RFID reader corresponds to the node, and each possible route of an RFID tag between readers corresponds to the edge. Figure 5 is an example of the graph.

- The server prepares the data area for restoring Accompany Constraint, as n sets of accompnying objects: $G_0, \cdots, G_n$ which changes dynamically as objects gathers or separates. The constraints obey the *Accompany Constraint Rules*, which is the rule for changing Accompany Constraint, previously configured before the initial execution. Although much work is necessary to establish the Accompany Constraint Rules, we present the simple rule: the objects identified in a particular reader are always grouped such as $G_i = \{Object4, Object10, User43\}$, and the group identified in a particular reader are always *un*-grouped.

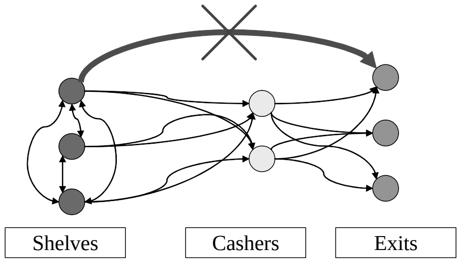

Figure 5: An example of Route Constraint

4.2 The system behavior of the reader side

Each RFID reader simply sends its ID and the IDs of the identified RFID tags when the identification events occur. Additionally, the reader side provides the input/output interface for the users or the peripheral devices when an error are reported from the server as described next.

4.3 The system behavior of the server side

The server's main operation is triggered by the signals sent from readers. When the server receives the signal that one or more tags $t_{r,1}, \cdots, t_{r,k}$ are identified in a reader r, the server behaves as follows:

1. For each tag $t_{r,j}$,

2. If $t_{r,j}$ is grouped in a group G_i, throw an exception *ACCOMPANY_EXCEPTION* if any tag $t \in G_i$ is not identified in $t_{r,1}, \cdots, t_{r,k}$.

3. Apply the Accompany Constraint Rules to r and $t_{r,1}, \cdots, t_{r,k}$, and update $G_1, \cdots, G_n$, in which some tags in $t_{r,1}, \cdots, t_{r_k}$ are added to or removed from a group G_l, or create a new group G_{l+1}.

4. Throw an exception *ROUTE_EXCEPTION*, if the edge doesn't exist in the Route Constraint Graph, in which the edge originates from the reader node r' which corresponds to the previous log of the tag identification $t_{r,j}$.

4.4 Improvement

Using the method shown above, FRED can improve the reliability of the Digitally Named World as follows:

- Accompany Constraint improves the identification of the objects which moves with other objects. In the supermarket example, if only $user43$ and $product4$ are identified at the casher for a group $G_i = \{Object4, Object10, User43\}$, $product10$ can be inferred to be identified by the Accompany Constraint stored on the server.

- Route Constraint improves, with the temporal log of the identification of any tags at any readers, the identification of the objects which obeys patricular possible routes. In the supermarket example, if a product once identified at a shelf was identified at an exit without identified at the casher, there may be either the product missed the auto-payment or it is to be stolen, and the reader at the exit can warn the customer to recheck at the casher.

We can easily imagine and solve the combined case of the two. If multiple products identified at a shelf, and if at least one of them are identified at an exit without being identified at the casher, the any of the products firstly identified products (grouped at the server) can be detected that they are missed to be payed.

Although the approach we propose can be effective to improve the reliability, it can not achieve the perfect reliability to the 100 percent. We show the case the system fails to identify all the trace of the products:

- When none of a group is identified, the failure of identifing the tags in the group cannot be detected.

- When some tags are misgrouped, the some wrongly ungrouped tags cannot be detected to be identified, or some wrongly grouped tags are assumed to be identified.

- If a tag isn't identified at the last several readers at the end of the route, it cannot be detected.

- If there is a loop in the route of a tag, the failure of the identification in the all readers in the loop cannot be recognized from the identification on the single reader at the start point (loop enter/exit node of the route) of the loop.

- If there is a parallel path from a node to another node, the identification error cannnot be recovered if all the node inbetween are not identified.

As many RFID readers are deployed in the world as one aspect of the pervasive computing environment, our approach becomes more important, since it is one that cooperates many affordable devices.

5 Conclusion

In this paper, we addressed the reliability in the Digitally Named World. In the Digitally Named World, the information in the real world is captured and transferred to the virtual world. Reliability is crucial for the Digitally Named World, because if unreliable capure or transfer occur, the effect of the Digitally Named World becomes small, none, or even worse. We proposed a method for improving reliability and eventually preserving the consistency in the Digitally Named World by exploitting simple model of the behavior of the target objects and networked readers.

Our approach is based on the incorporation and utilization of some real world constraints into the reasonable and feasible constraints in the virtual world. These approach can be / should be generalized to incorporate more effective constraints in the real world, such as total weights, visual information, sensor data.

References

[1] P. Hewkin, "Smart Tags - The Distributed Memory Revolution". IEEE Review (1989).

[2] S. Konomi, "QueryLens: Beyond ID-based Information Access". To appear in: Proc. 4th Int'l Conf.Ubiquitous Computing (Ubicomp2002) (2002).

[3] Sozo Inoue, Shin'ichi Konomi, and Hiroto Yasuura, "Privacy in the Digitally Named World with RFID Tags", *Workshop on Socially-informed Design of Privacy-enhancing Solutions in Ubiquitous Computing*, Sep. 2002.

[4] Shin'ichi Konomi, "*QueryLens*: Beyond ID-based Information Access", *Proceedings of 4th International Conference Ubiquitous Computing (Ubicomp 2002)*, Oct. 2002.

[5] Shin'ichi Konomi, "Snap-On Filters for Mobile Information Appliances", *Proceedings of 5th Asia Pacific Conference on Computer Human Interaction (APACHI 2002)* , Nov. 2002.

[6] R. Want, K. P. Fishkin, A. Gujar, B. L. Harrison, "Bridging Physical and Virtual Worlds with Electronic Tags". Proc. Int'l Conf. CHI 99 (1999) pp. 370–377.

[7] Harald Vogt, "Efficient Object Identification with Passive RFID Tags", *Proceedings of International Conference on Pervasive Computing*, Aug. 2002.

[8] M. Weiser, "Some Computer Science Issues in Ubiquitous Computing". Communications of the ACM, 36(7) 1993, pp. 75–84.

[9] M. Langheinrich, "Privacy by Design - Principles of Privacy-Aware Ubiquitous Systems". Proc. 3th Int'l Conf.Ubiquitous Computing (Ubicomp2001) (2001).

[10] X. Jiang, J. Landay, "Modeling Privacy Control in Context-aware Systems Using Decentralized Information Spaces". IEEE Pervasive Computing, Vol. 1, No. 3, (2002).

[11] Finkenzeller, K. , 「RFID Handbook」, Nikkan Kogyo Pbl. Japan (2001).

[12] http://www.narita-airport.or.jp/naa/airport/greenport/2001_11_12/06_news.pdf.

[13] Sanjay E. Sarma, Stephen A. Weis, Daniel W. Engels, " Low Cost RFID and the Electronic Product Code ", Proceeding of Workshop on CHES 2002, Aug. 2002.

[14] MIT AUTO-ID Center Homepage, http://www.autoidcenter.org/.

[15] Japan Railway Co. Ltd. East, "Suica Card", http://www.jreast.co.jp/suica/.

[16] Hitachi Co. Ltd., "Myu Chip", http://www.hitachisemiconductor.com/sic /jsp/japan/eng/gain/135/next/