A Smart RFID System

[1]Min Chen, [2]Runhe Huang, [3]Yan Zhang, [4] Han-Chieh Chao
[1] School of Comp Sci & Eng, Seoul National University, Seoul, Korea (minchen@ieee.org)
[2] Faculty of Computer and Information Sciences, Hosei University, Tokyo, Japan (rhuang@hosei.ac.jp)
[2] Simula Research Laboratory, Norway; IFI, University of Oslo, Norway (yanzhang@ieee.org)
[4] Institute & Dept. of Electronic Engineering, National Ilan University, Taiwan (hcc@niu.edu.tw)

***Abstract*—Radio frequency identification (RFID) is a kind of electronic identification technology that is becoming widely deployed. Compared to traditional RFID system, tags in the proposed smart RFID system would store not only the fixed ID information but also some information which is "active" and encoded in the form of mobile codes indicating the up-to-date situation and associated services' directives. In the proposed system, the service that the RFID tag bearer needs can be explained in a context-aware decision making system to provide a situation-aware system response and offer a good quality of service (QoS).**

I. Overview of Traditional RFID System

A typical RFID application consists of an RFID tag, an RFID reader, and a backend system. With a simple radio-frequency (RF) chip and an antenna, an RFID tag can store information that identifies the object to which it is attached.

Fig. 1 shows an example of a typical application for vehicle access control in traditional RFID system. Here, an RFID tag is carried by every vehicle that needs access to one or more restricted areas. When the vehicle moves within the transmission range of an RFID reader, the identification data of the vehicle will be transmitted to the processing module in the backend system, which associates the vehicle ID with a pre-existing rulebase entry. This rulebase maintains a list of identifications and their associated rules, which are matched against the conditions required to issue an action for a specific object's ID. After obtaining the corresponding rule from the rulebase, the system checks whether the required condition is satisfied in order to initiate the appropriate action. In our example, we assume that the process of rule matching with the vehicle's ID is successful, and that this outcome is forwarded to the processing module. There, if the condition of the rule is judged to be satisfied, then the gate will be opened to grant the vehicle permission to enter. Otherwise, the vehicle is not allowed to enter. The process of rule-searching in the rulebase is the key operation performed in traditional RFID system. However, this is also the part of the system operation where many problems arise. Returning to our example, if the vehicle's ID is not registered beforehand in the rulebase, then the driver may need to seek manual intervention, which may be time-consuming or ineffective if handling emergency situations. A similar situation occurs when the associated rule is out-of-date due to new requirements from the driver, and/or special checking requirements for the products loaded on the vehicle.

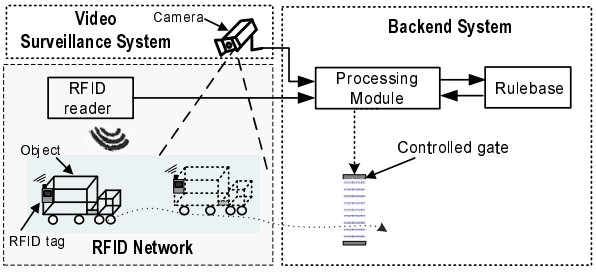

Fig. 1. A typical example of traditional RFID system for access control.

II. A Smart RFID System

Compared to traditional RFID system, tags in smart RFID system would store not only the fixed ID information but also some information which is "active" and encoded in the form of mobile codes indicating the up-to-date situation and associated services' directives [1]. Thus, the regular process of rule-searching and its associated issues seen in traditional RFID system can be averted.

The basic format of such mobile code can consist of a simple conditional statement and a series of action codes in abstract level:

if condition (environmental parameters) **then**
    <action1 (parameter1)>;
    <action2 (parameter2)>;
    · · · ;
end if

where environmental parameters (e.g., temperature or humidity sensed by some sensors, etc.) are used to determine whether the condition of a rule is satisfied, and action represents the operation/service that the system can provide for the object. Given the example in Fig. 1, the mobile code stored in the tag of the smart RFID system can be:

if Time < 11pm **then**
    open_the_gate();
end if

To extend the capability of the basic RFID system, other technologies can be integrated with RFID technology to enable a wide range of applications. In our example, a video surveillance system can be employed to enhance the security level in addition to the vehicle-entrance-controlling service. Smart RFID system could easily associate the extended capabilities of existing systems with the object-specific requirements, without the need for any human operation and input to the rulebase. The corresponding mobile code stored in the tag of a smart RFID system can be simply changed to:

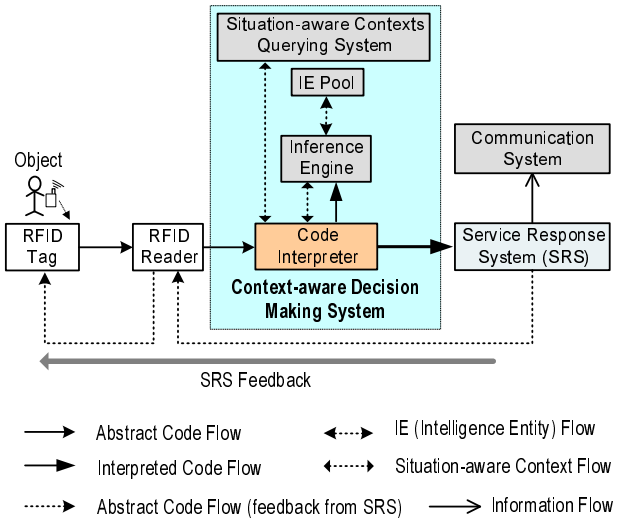

Fig. 2. Illustration of the Smart Code and Smart RFID system.

if (Time $<$ 11pm) $\vee$ (check_number_plate() = 1) **then**
    open_the_gate();
else
    trigger_alarm();
end if

where $\vee$ denotes the logic operator to unify two conditions into the situation sentence.

The additional condition checking "check_number_plate() = 1" is used to verify the image of the vehicle's number plate. Therefore, if the RFID tag is stolen and attached to another vehicle, then this condition would not be satisfied. Here, the function of the "check_number_plate()" directive needs to be recognized and executed by the service response system. This function will activate the video surveillance system to capture a picture of the vehicle's number plate. If the number recognized from the picture of the number plate matches the existing plate number, the gate is opened. Otherwise, the gate remains closed, possibly followed by some alarm signal being triggered. As illustrated in the previous example, smart RFID system provides more flexibility and scalability, and supports various applications in an on-demand basis.

III. Architecture of the Smart RFID System

Fig. 2 shows the functional components of our proposed smart RFID system, which mainly includes Intelligence Entity (IE) pool, inference engine, code interpreter, situation-aware contexts querying system, communication system and service response system:

- *Intelligence Entity (IE) Pool*: The intelligence entity pool (IEP) is the core of intelligence entity sharing, and the main issue of an IEP is to choose an appropriate knowledge representing structure, with which an intelligence entity can be flexibly composed and decomposed [2].
- *Inference Engine*: An inference engine usually corresponds to a kind of knowledge representation, and how the associated inference engine works with the tree-structured knowledge base. It is also realized as a middleware layer with the role of hiding the management complexity of RFIDs to support their integration within the background business systems.
- *Situation-aware Contexts Querying System*: This module is used to retrieve the environmental parameters that facilitate the inference engine's decision making task. Some example systems include wireless sensor networks, video surveillance system, wireless body area networks, and positioning system, etc.
- *Service Response System*: It carries out the desired tasks in accordance to the decision made. If an action/service is requested, then the action manager executes the necessary processes to perform such an action. The output of an action can vary according to the different types of systems.

In order to tell system what an object needs in a timely fashion, a situation-aware unit is needed, which motivates the introduction of mobile code, the situation-aware code delivery, interpretation and update in the smart RFID system:

- *The Delivery of Mobile Code in Smart RFID System*: Since RFID tag has no processing power, it only works a carrier for mobile code. Once an object moves to the proximity of a RFID reader, the information stored in the tag will be delivered to the reader, as shown in Fig. 2. The communication process of code delivery is simple. However, the main challenging issue during code delivery is to guarantee security and privacy.
- *The Interpretation of Mobile Code in Smart RFID System*: Due to the limited capacity of RFID tag, the mobile code only contains a small size of abstract code, the abstract code needs to be interpreted into a detailed message which can be recognized by an inference engine. As shown in Fig. 2, the context-aware decision making system is an intelligent processing system to produce a solution to a real world situation. While the mobile codes are dynamically written in depending upon the changing situation, the intelligent processing system which is hidden behind the backend system can be exploited for adaptation to the changing situations.
- *The Update of Mobile Code in Smart RFID System*: In order to provide on-demand quality of service, it should be possible to change or re-write the mobile code in an on-demand fashion, which includes active and passive code update.

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