Application of Radio Frequency Identification Technology to Toll Collection System

TATSUYA HIGUCHI*1 KAZUYOSHI KITAJIMA*2

KEIJI TERASAKA*2 KYOKO OSHIMA*2

SHINICHI MASUMOTO*3 MASAFUMI SATO*4

In recent years, electronic toll collection (ETC) systems that levy tolls using radio communication have been increasingly introduced in Asia in order to alleviate the traffic congestion that occurs at tollgates on expressways. However, there are cases where the growth of the penetration rate of ETC systems is sluggish because the ETC on board unit (OBU) is expensive. Under such a situation, the practical application of a toll collection system using a low-cost sticker-type RFID (Radio Frequency Identification) tag as an OBU can establish a system that benefits both expressway operators and users.

This paper describes efforts toward the practical application of a toll collection system using RFID communication technology.

1. Introduction

Since the late 1990s, ETC systems that levy tolls using radio communication instead of cash have begun to be introduced in various countries around the world in order to alleviate the traffic congestion that occurs at tollgates. ETC OBUs currently used are broadly classified into the following three types depending on their features:

(1) High-function type

An OBU used in an autonomous toll collection system that levies tolls according to the passed toll points or the travel distance determined based on the location information measured by the OBU using GNSS (Global Navigation Satellite System). This device can also provide the driver with various types of information including travel route and road conditions utilizing the current location information. The OBU is used in Singapore's next-generation ERP (Electronic Road Pricing) system (**Figure 1**), which is under development as of 2016, falls under this type.

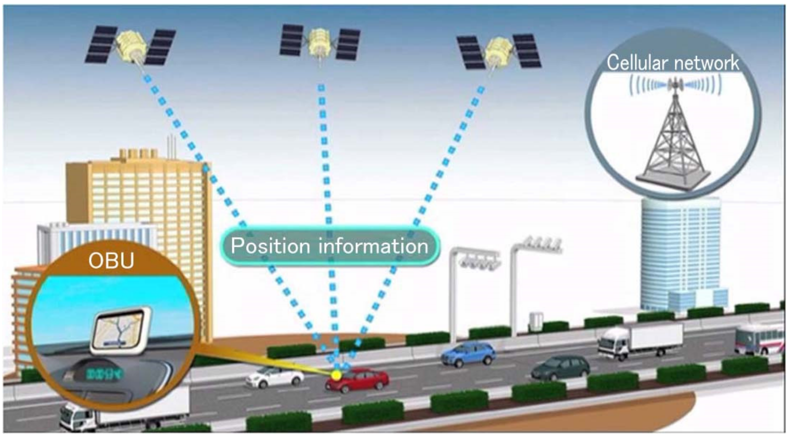

Figure 1 Singapore's next-generation ERP

*1 Chief Staff Manager, System Technology Development Department, ICT Solution Headquarters
*2 System Technology Development Department, ICT Solution Headquarters
*3 System Technology Development Department, ICT Solution Headquarters, Professional Engineer (Kuala Lumpur Liaison Office)
*4 ITS Division, Mitsubishi Heavy Industries Mechatronics Systems Ltd.

(2) Single-function type

An OBU with a single function to communicate with a roadside unit (RSU) installed mainly at toll points on expressways and make a payment according to the toll calculated by the roadside system. The payment of tolls uses IC cards such as prepaid cards or credit cards. When a vehicle equipped with this type of OBU passes a toll point, the OBU announces the paid toll and records the payment history on the IC card. This type includes Singapore's current ERP system (**Figure 2**) and the existing Japanese ETC system (**Figure 3**).

Figure 2 ERP system OBU

Figure 3 ETC system OBU

(3) Limited-function type

An OBU consisting of a sticker-type RFID tag that requires no power source (**Figure 4**). RFID readers installed in tollgates read the identification information of the RFID tag affixed to the windshield of a vehicle and charges the user through the bank account associated with the identification information. The function of the RFID tag is limited to the identification of the vehicle, and it cannot announce the paid toll or a record of the payment history. Due to the low cost of RFID tags, however, this type has attracted attention recently in emerging countries such as those in Asia and Latin America.

Figure 4 RFID tag

All of the aforementioned types are available in order to meet various toll collection demands around the world. This paper describes our efforts toward the development and practical application of a toll collection system using RFID communication technologies as shown above (3).

2. Development of RFID reader

The RFID communication technologies utilized for these efforts read identification information recorded on RFID tags using a UHF band (900 MHz band) RFID reader. The sticker-shaped RFID tag incorporates only an IC chip and an antenna. Because the IC chip driving power is supplied by radio waves from the RFID reader, the RFID tag requires no battery.

As current commercially-available products, RFID communication technologies are generally used for the purpose of item management in a wide array of logistics applications. There are only a few products on the market that are optimized for the toll collection systems of expressways, etc. As such, there was a need to develop an RFID reader that satisfied the following conditions:

(1) Compliance with standards

An open communication interface and communication protocol that conform to international standards ISO18000-6C[1] and EPC Global Class 1 Generation 2[2] shall be adopted in order to maintain compatibility and attain interconnectability with RFID tags currently on the market and facilitate the acquisition of a radio license in the destination countries.

(2) Establishment of communication area suitable for toll collection systems and interference prevention

The RFID reader shall be installed overhead at the ground height of approximately five meters and a narrow band communication area shall be established while maintaining the radio wave output sent from an RFID reader antenna within the designated radio wave range so that secure radio communication with an RFID tag affixed to the windshield of a vehicle passing directly under the RFID reader at a high speed can be made (**Figure 5**).

In addition, the sending output of radio waves shall be able to be remotely controlled externally in order to easily adjust the communication area.

Moreover, for the prevention of interference, a function to divide the radio wave into channels with different frequencies (FDMA: Frequency Division Multiple Access) and a function to divide the radio wave output timing through timing intersynchronization between multiple RFID readers (TDMA: Time Division Multiple Access) shall be provided (**Figure 6**).

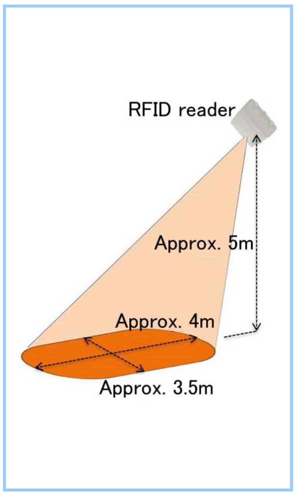

Figure 5 RFID reader narrow band communication area

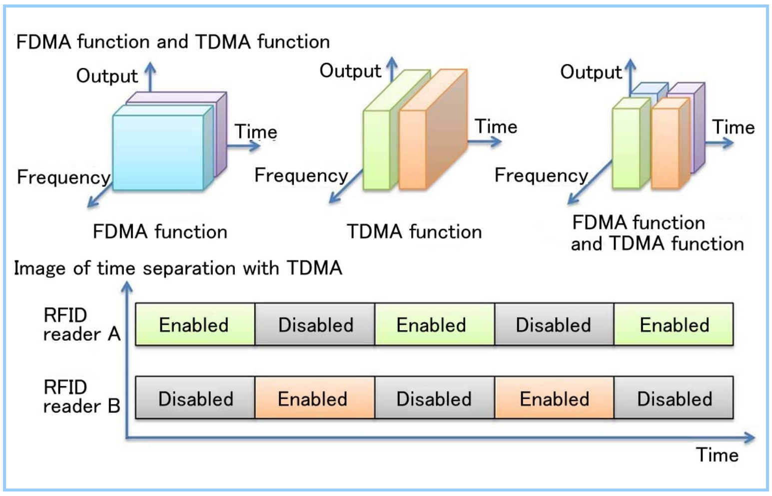

Figure 6 Prevention of radio wave interference using FDMA and TDMA

(3) Expandability of security functions

A security function using an authorization algorithm to validate the authenticity of an RFID tag shall be able to be added in order to prevent unauthorized use such as spoofing. It should be the authorization algorithm to be customizable for each expressway operator. Moreover, the calculation speed of the authorization algorithm shall be high enough that vehicles travelling at the maximum legal speed of the expressway can be processed.

Figure 7 External view of RFID reader

Table 1 RFID reader specifications

No.	Item	Description
1	External dimension	210(W)×210(D)×130(H) mm
2	Weight	1.5kg
3	Power source	24VDC. Current consumption, 1A or less.

The development of an RFID reader that satisfies all of the aforementioned conditions essential for a toll collection system with advantages for expressway operators such as ease of installation and software development as shown below was completed in March 2016 (**Figure 7**) (**Table 1**).

(1) Ease of equipment installation

An all-in-one type RFID reader containing an antenna and controller in a single body was realized due to the design of a simple and reliable circuit. This allows space saving and wire saving in installation on tollgates and leads to a reduction in the duration of lane closings for installation (**Figure 8**).

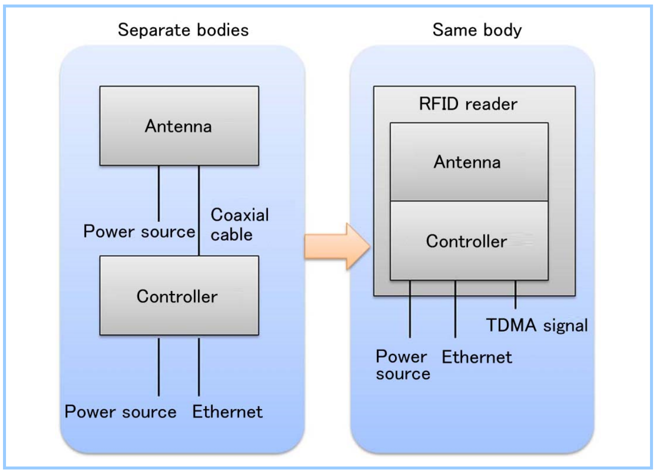

Figure 8 Ease of equipment installation

(2) Library for development of RFID reader software

A library for the development of RFID reader software compatible with various development environments including OS platforms, C, Java, etc., was developed in parallel in order to facilitate retrofitting to existing toll collection machine systems. By installing the RFID reader control driver contained in this library, the existing toll collection machine system that is the upstream system of the RFID readers no longer needs to consider the details of RFID communication, allowing the number of man-hours required for the development of software needed for the incorporation of our RFID reader to be minimized (**Figure 9**).

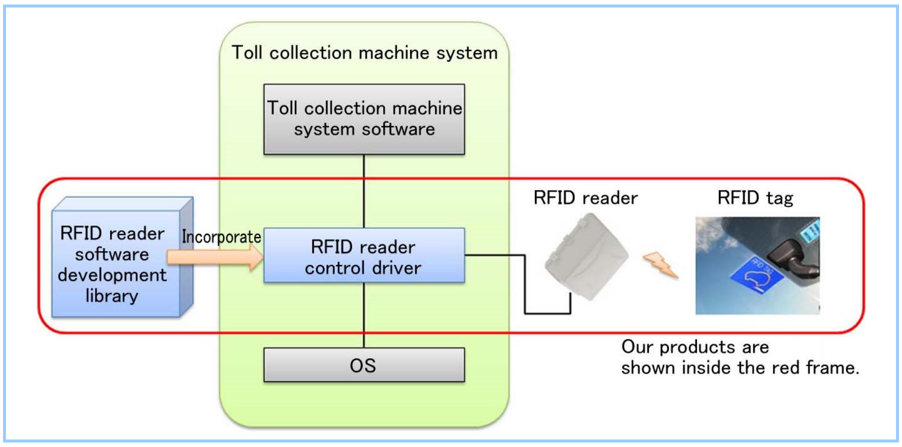

Figure 9 RFID reader software development library

3. Efforts toward practical application of RFID system

(1) Efforts toward practical application of single lane ETC

In Malaysia, where an infrared ETC system has already been in service since 1998, the practical application of an RFID system to expressway toll collection is being considered under the leadership of the Malaysian government, targeting the pracitical use of a next-generation ETC system sometime after 2017.

We are also taking part in field tests at expressway tollgates. As of June 2016, we have installed RFID systems in six lanes at five tollgates. Through the efforts in the real environment shown below, the applicability of RFID to ETC systems was confirmed (**Figure 10**).

- Acquisition of a radio license in Malaysia
- Measurement of RFID system communication performance through a running test with actual vehicles
- Test for the confirmation of interconnectability with RFID tags issued by multiple companies
- An environmental test on the assumption of the tropical climate and its field verification

Figure 10 Field test in Malaysia (single lane ETC)

(2) Efforts toward practical application of multiple-lane free flow system (MLFF)

As a further evolutionary form of a single lane ETC toll collection system, an MLFF system that eliminates tollgate islands and gate barriers and enables toll collection for vehicles travelling in any lane among multiple lanes is also being considered in parallel for practical application (**Figure 11**).

In 2015, we developed and constructed, in cooperation with Malaysian companies Touch'n Go and Quatriz, an MLFF gantry in Technology Park Malaysia as a verification test facility. Since then, data collection and the analysis of thousands of vehicles a day has been carried out.

Our advocated MLFF system consists of an RFID reader installed on a gantry that spans a road and a camera-based license plate recognition device. Important key technologies of an MLFF system include vehicle ID recognition using an RFID reader for single lane ETC, image recognition of the license plate intended for the control of vehicles with no RFID tag, and the integration of this information.

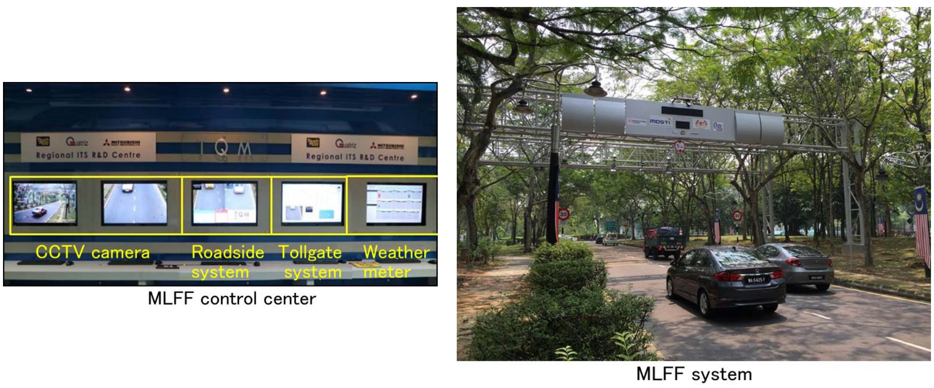

Figure 11 Field test in Malaysia (MLFF system)

4. Conclusion

As technological problems with RFID systems in the practical application of a single lane ETC system have been overcome, it is necessary in the future to focus on the migration management of bank account management systems and toll collection machine systems that are already being operated by multiple system integrators.

For the practical application of an MLFF system, on the other hand, data collection and analysis based on actual operation on a real expressway in consideration of various vehicle types and vehicles travelling at a speed higher than the legal speed limit are required.

In particular, we believe it is necessary to enhance technology for the image recognition of license plates that are even difficult for the human eye to recognize, and to extract problems in controlling unauthorized vehicles and take countermeasures, including the enhancement of the quality of the license plates themselves.

The toll collection system using RFID communication technologies is expected to raise the penetration ratio of ETC due to the low cost of RFID tags and contribute to elimination of traffic congestion. We will promote the expansion of the RFID system to Asia beginning with practical application in Malaysia.

References

(1) ISO/IEC 18000-6 Information technology – Radio frequency identification for item management Part 6: Parameters for air interface communications at 860 MHz to 960 MHz" , International Organization for Standardization ISO Central Secretariat 1, ch. de la Voie-Creuse CP 56 CH-1211 Geneva 20 Switzerland.

(2) EPC global Class-1 Generation-2 UHF RFID 860 MHz – 960 MHz", Distribution Systems Research Institute, Place Canada 3rd Floor. 7-3-37 Akasaka, Minato-ku Tokyo 107-0052, JAPAN.