

ETC development pushes combination of RFID and ITS

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Abstract—The combination of Radio Frequency Identification (RFID) and Intelligent Transportation System (ITS) makes the Electronic Toll Collection (ETC). On one hand, ETC can help the recovery of the investment in transport infrastructure. On the other hand, it is also an effective way to ease traffic congestion in the charging station area, thus reducing environmental pollution. So nowadays, many countries first develop ETC to accelerate the development of the national Intelligent Transportation. With serious traffic problems, the application of ETC in China is widely promoted. In this paper, ETC in China is taken for an example to introduce the key technologies of it and to explain how it works to improve traffic quality.

Keywords- ITS, transportation, ETC, RFID

I. INTRODUCTION

In Queensland of Australia, "smart bridge" is being developed. Through a variety of sensors installed on the bridge, the bridge can tell the city managers the number of vehicles, the weight cars, how much car pollutions, whether the car is new or used one etc. Besides, the pressure that vehicles bring to the concrete of the whole bridge could also be calculated and sent to the managers. So traffic management department can assess the information and acquire the data of structural strength of the bridge. Once the pressure exceeds the limit, the traffic management department would get alerts and quickly deal with it. And this is only a small reflection of improvements in ITS establishment, however, it is announcing that the era of ITS is coming. Electronic Toll Collection (ETC) is the world's most advanced charging system, and is also one of the most important services of the intelligent transportation system. The passing vehicles can go through the crossing without stopping and will be automatically charged. It is especially suitable for heavy traffic on the highway or bridge and tunnel. If there is no ETC system, every vehicle passing the toll station will have to stop, pay and then move on. Though this process is not long and just needs ten seconds or so, the wasted time added up together is going to be a very impressive figure, which will undoubtedly affect the efficiency and the smooth of highway transportation, or even cause traffic congestion and serious economic losses. (Al-Deek & Mohamed 1997) And in China, with the largest population over the world, this problem seems to be more complicated. So Chinese government is trying to handle it, and the solution is to improve ETC system. And that is why recent years China's ETC has made some big progress. This paper will first review the forming international standards about ETC and tries to explain

some details. And then the main technologies as automatic vehicle identification technology and automatic Vehicle Classification System are introduced. What's more, this paper also draws a very comprehensive constructor of ETC system and displays how it works. And some advices on China's ETC developments are given at the end of this paper.

II. LITERATURE REVIEW

Expressway charging is becoming a big problem in many countries these years. In order to solve this problem, governments are actively developing ETC system and many countries have entered a practical stage. ETC System, that is, no stop electronic toll collection system consisting of the use of RFID technology, communications and network technology, sensor technology, image recognition and other high-tech equipment and software. It enables automatic identification of vehicles, check statistics and some other real-time processing. (Kirschner 1997) In Europe, America, Japan and other developed countries and regions, ETC systems have been installed on some highway. And the vehicle's top speed through the toll is even up to 200 km / h, effectively easing the traffic congestion situation caused by parking for paying. Practice has proved that using ETC system is not only a fundamental solution to overcome the slow travelling process due to manual toll, but also can reduce the cost of fees, vehicle fuel consumption and air pollution, resulting in significant social and economic benefits. Internationally, the standardization research of DSRC is mainly carrying out in Europe, US and Japan. CEN/TC278 of Europe and ISO/TC204 of Japan were completed the work of DSRC standards in 1997, choosing 5.8GHz as the DSRC communication frequency. Before 1998, researchers of the United States had been discussing to take 915MHz to be the standard of DSRC. On May 19th, 1997, ITS America suggested to distribute 5.850-5.925GHz to the field of intelligent transportation services and retained 915MHz for the recent application of ETC system, which was adopted by the Federal Communications Commission (FCC). So far, three of the world's basic research points have been unified on the 5.8GHz frequency band. (Riley 2008) By taking full account of international trends of DSRC standardization and the national status of intense requirements about application of ETC system, The Commission of China ISO/TC204 suggested that China had no time and there was no need to re-develop a new set of ETC standards and it would be the most practical way to adopt of existing mature international standards. In May 1998, the Commission of China ISO/TC204 proposed to Committee

China Radio Management Commission proposed to assign 5.8GHz frequency band to the field of intelligent transportation system technology of short-range communications (including ETC systems) and the Radio Management Committee agreed to do so. The reasons of China's choosing 5.8GHz frequency band to be center of the microwave short-range communications are that China's communication standard system is similar to the European one, the allocation of radio frequency resources are roughly the same (900MHz mainly for mobile communication systems, 2.45GHz for medical equipment and home microwave apparatus, 5.8GHz for health communications, industrial, military, scientific research and spread spectrum communications). As 5.8GHz frequency band is with less background noise and can avoid frequency interference, which is a big advantage over that of 915MHz and 2.45GHz. What's more, suppliers of 5.8GHz band are more conducive, which is good for the introduction of ETC system equipment and help to reduce system cost. Although the ETC is considered to be a greatest revolution about the prospects for widespread, its development in China is not always so smooth. Shanghai is taking the lead in the promotion of ETC, but also experienced first blow. Since 1999, Shanghai Urban Construction Group started to develop ETC system, which was selected by the China's Ministry of Communications and the project was identified as national technical innovation and industrialization project by the State Economic and Trade Commission. However, to the experts' surprise, this new technology could not blend in this country. Although after 3 years' promotion, there are no significant improvements in ETC application in highway charging. And this is not just occurring in Shanghai, but all through China. (Levinson & Elva 2003) Worse still, the requirements for new technologies and great funds are also influencing the development of ETC in other countries. In the process of implementation of ETC in Japan, as there was no adequate market research and analysis done on the economic affordability, resulting high price in market when putting into use. So this system is getting its cold reception in the market, the numbers of drivers that initiative to install electronic tags much smaller than the number expected. (Ogden 2001)

III. KEY TECHNOLOGIES AND MAIN STRUCTURE OF ETC

According to fig1, it could be seen that in Japan nearly 70% people use roads in their daily life. And the use of ETC system, to some degree, will largely reduce their waiting time at the toll station, thus improve the transportation environment. (Kaneko et al 2002) In this part, the key technologies and main structure of ETC is going to be introduced, and just see how they work.

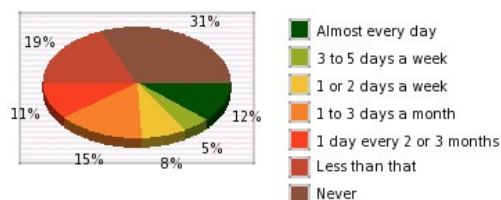


Figure 1. How often do u use toll roads? (From: research of DIMSDRIVE in Toyota covering 7,287 members in November 2007)

The world-renowned corporation, Harbor Research Inc, is working on providing strategic consulting and research services. Fig1 and fig 2 are the resources coming from it, which are showing that today there are 110 million global M2M devices being in use in an Internet access to communicate with each other. By the year of 2010, worldwide revenues associated with M2M device will be more than 250 billion U.S. dollars. And till 2011, M2M revenues worldwide will reach 290 billion U.S. dollars. According to predicts of the analysis company, Berg Insight, by 2011 North American's M2M devices will reach 66 million units, much more than the 9,000,000 in 2006. Alexander Resources advisory also mentioned that M2M market capacity was from 240 billion dollars in 2004 increasing to 470 billion dollars in 2010. Analysts say that M2M has reached a turning point and will shift to faster development. With many years experience in the cellular M2M industry research, analyst Sam Lucero from ABI Research indicated that in the next few years the M2M industry would be with 25% of annual growth, while its services revenues would increase to 80 billion U.S. dollars in 2012. M2M technology concludes IT technology, control technology, management technology, which has made it clear that M2M industry can only through mutual cooperation will it achieve fast development.

A. Automatic vehicle identification technology

The subsystem of Automatic vehicle identification Systems (AVI) mainly adopts RFID technology, and is the core of ETC systems. With IC card as a data carrier, it can achieve remote data access between computer and IC card via wireless data exchange. And information as vehicle type, owner of vehicle, license plate number, road running and levy state is all stored in IC card. (Jones & Davis 2010) AVI is made up by On Board Unit (OBU) also known as car tag, Road-side Unit (RSU) and Pressing Data Unit (PDU). OBU stores the recognition code and relevant vehicle data, when the vehicle goes into the RSU identification section, OBU can immediately transfer these data to RSU, working as vehicles' identification. What's more, it also accepts and record the data sent by the RSU. RSU equipments are installed on the road side or above the road, which was mainly used to read and process the data of vehicle identifications coming from OBU. And after that RSU will send the processed data to PDU. So RSU is a very important connection in the communication between OBU and the PDU. After PDU gets the data from RSU, it will verify the vehicle identification and carry out the operations of calculating and controlling. Or it also sends relevant data to the OBU through the RSU. ETC can be divided into read-only system and read-write system according to Information collecting tag and reader functional classification. (Umeda et al 2002) Based on whether the tag is with power, ETC system can be classified by active and passive systems. Communication distance of active tags can be designed available for adjustment in the area of 5-25 meters, which is convenient for transportation management in different sections. Besides, with the advantage of fast information transmission and the reliability of two-way communication, the international multi-ETC system is all using active RFID technology. (Uchida & Matsuda 2002)

1) Automatic Vehicle Classification System

Road pricing is according to vehicle classification. Automatic Vehicle Classification Systems (AVC) is a comprehensive reflection of modern technology, which distinguishes the type of vehicles through the way of contactable or contactless measurement of the physical characteristics of the vehicle. There is also a simple way by reading the vehicle type information in the vehicle control. Completing the classification of vehicle types before cars achieving the toll station is called the former classification system of AVC, while the one completing the classification after is called the after classification system. The former classification system of AVC is to calculate the vehicle rates according to the classification results. However, the after classification system is used to verify whether the vehicle is in accordance with the model adopted by the implementation of the correct charges. The former classification system of AVC is as the basis for charging and with great requirements on the system. The sub-type data of the after classification system is used as an after checking and sometimes the video data can be transferred to verify the vehicle, so its system requirements are lower.

B. The composition of ETC system

ETC system is mainly composed of ETC toll lane system, toll station management system, ETC management center and the transmission network. According to the division of labor, the system can be divided into front part and back part. Front part is consist of the lane system and toll management system, completing the identifications on vehicle passing by, imaging illegal vehicles, as well as collecting and processing charging information.

1) ETC toll lane system

Lanes of ETC system is divided into ETC / MTC Hybrid Drive and the ETC special lanes. And the ETC special lanes can also be divided into high-speed ETC lanes and low-speed ones, among which high-speed ETC lanes can be subdivided into free flow of single lanes and that of multi-lane. Free-flow of multi-lanes are widely taken into use and the lane equipments are: microwave reader controller (including the antenna and controller); lane controller, drive computer; vehicle detector, drive camera, fees monitor, traffic lights, sound and light alarm, automatic railings, characters adder etc. According to functions, ETC lanes system can be divided into entry drive module and exit drive module. Entry drive module refers to the entrance of highway vehicles while exit drive module is the exit of highway vehicles. First, by controlling the lights and signs of entry drive module, drivers are guided to into the correct ETC toll lane. When the vehicle passes the monitor, the sense coil of the vehicle will wake up AVI system, then road-side reader (RSU) provide the entrance lane information for car tag, after judging by PDU, legitimate users of ETC will be released, separated from the illegal entry of vehicles. Finally, the information of entry drive will be uploaded to the toll management system. And exit drive module also works in a similar way.

2) Toll station management system

Toll station management system concludes computer system, control system and communications system. Computer system is made up of data processor, image processor, network

servers and computer networks of computer components drive. Control system consists of toll lane monitoring cameras, network image processing unit (Image recording and display). Communication system can use optical fiber to transfer information, or even DDN line and ordinary telephone lines. Functions of toll station management system are as follows: Establishing data and image information of fees and the original traffic flow; getting real-time information of vehicles at the entrance lane; getting real-time transaction records of exit lane and real-time image of illegal drivers; receiving the blacklist from company's computer system and pass them to the control computer of lanes; handling the statistics, storage and analysis on charges and the data of traffic flow; helping in the information exchange between lane systems and management center; processing and image of uploaded illegal vehicles and receiving and issuing blacklist and yellow list etc. (Ryoo 2006)

3) ETC management center

Management center plays a key role in the ETC system, which is to process and exchange the pricing information and data as well as carry on management functions. It includes Franchise Company, settlement center and customer service center. Franchise Company is with the central management subsystem and responsible for all fees and charges collected by the ETC toll lane system. Management center of Franchise Company will classify and summary the data of ETC charge and artificial charge. And then the list of ETC toll after arrangement will be forwarded to the clearing house to ask for pay. Functions of sub-system of the central management are: collect toll data timely; finishing ETC toll data; deal with illegal behaviors that lane control system cannot handle; upload the list of ETC toll to ask for pay; summary and print charges data introductions in various ways etc. Settlement center is mastering data of fees in the whole system, responsible for significant financial settlement work. Generally, it does not directly deal with the work for ETC users. Settlement center manage the funds by transferring them to the bank. Also, according to effective founds in accounts and ineffective vehicle tag list, and these information is all transferred to subsystem of the franchisee under the central management. Its specific functions are: to establish and maintain financial accounts for ETC users; to generate ETC system blacklist and yellow list and pass them to the franchisee under the central management system; to receive the fee data uploaded by the central management system of franchisee company and update the founds in the ETC user accounts according to the charge data; assign tolls to each franchisee according to the data charges etc. Customer Service center is mainly to conduct the electronic label procedures for ETC users and deliver electronic tags to ETC users as well as handle the initialization of the label. Things like breakdown of inquiry, replenishment, printing services are provided for ETC users there. Business requests such as reporting the loss and cancellation of ETC users are also being met here.

IV. CONCLUSIONS

Recent years, China's booming economy has amazed the world, which directly led to a significant increase of vehicles. And that is why it is more severe congestion at the toll stations

of highways and bridges. So in China, the demand for the ETC system is even more urgent than western countries. The blocking of vehicles at the toll station is not just a waste of time but also a great loss of resources at the same time causing serious pollution. And ETC is going to be the future development of ITS establishment. However, China is a developing country with slow highway construction and weak infrastructure. The regional economic development does not match that of market demand. Besides, a lot of Chinese drivers are still embarrassed over a lot of transport fares. And there are no market conditions or capital base for the large-scale implementation of ETC network. From the current situation of ETC applications abroad, it works mostly in regional networking. And the state ETC network is limited to small countries, such as some European countries and Singapore. China is with vast territory, the ancillary service mechanism as national credit system networking, computing and data communication transmission network based on market conditions is imperfect. However, ETC system and highway network is closely related to these technologies. Therefore, China needs a long-term, rigorous certification process to form the standard of ETC network, which can not be away from the facts, conditions or rush to copy the implementation of foreign standards. For it is not good for market regulation but lead to great loss of funds and assets in highway construction. China has a vast market and the immediate needs for ETC, which is predicted that electronic toll collection would meet its bright future in China. However, it needs a slow process and should develop a proper ETC system according to the domestic situation.

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