The Research and Development of the Highway's Electronic Toll Collection System

Guang-xian Xu, Jian-hui Liu, Zhi-yong Tao, and Xin-chun Li

***Abstract*—**ETC (Electronic Toll Collection) is an electronic automatism toll collection system that was been researching by the world used in the highway, bridge and tunnel. Throwing information change between electronic labels that held vehicle and RPID antennas that was fixed the roadside or door frame, the center control computer can identify the road user by the information stored in the electronic label and deduct the pike from the road user advance stored card or bank account. Its obvious advantage is no parking troll collection. Thereby it can significantly improve the dispose efficiency of the toll station and the traffic ability of toll road.

***Keywords*—**Electronic toll collection, Vehicle identification technology, Electronic label, Infrared wireless communication.

I. Introduction

ETC (Electronic Toll Collection) is an electronic automatism toll collection system that was been researching by the world used in the highway, bridge and tunnel. Its obvious advantage is no parking troll collection. The vehicle can at high speed throw the toll station instead which has to slowdown before toll station and park to charge.

Along with the development of motor transport, the use of highway traffic will be more and more. (This trend is very clear in electronically developed areas.) The charge form of manual and semi-manual will not meet demand of the charging management system and arose many vehicle blocked at entrances and exits causing huge economic losses when it reached a certain threshold. The use of no parking on the highway shows a great potential in solved these problems.

II. The Composition and Principle of ETC System

ETC system's can wireless communication and information change by the device fixed in the vehicle and road head device which was fixed in the toll station's roadway. It composes by automatic vehicle identification system, center control system and other ancillary facilities.

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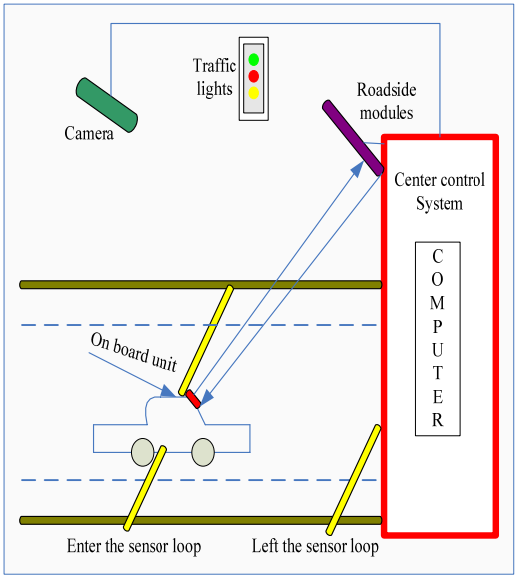

Fig. 1 The principle of ECT system

The system of automatic identification vehicle is composed by on board unit, road side unit, loop sensor and other components. And the center control system is consisted of large database and the information of enrolled vehicles and users. When vehicle pass the toll station gob, loop sensor apperceive the vehicle; RSU sends out question signal; then OUB responds and done two-way communication and data exchange. Center control system fetch the identify vehicle information like as car's ID and car's module and compare these information to the database. According to situation, it controls the center manager system do different operation. Such as computer charge manager system deducts these traveling expenses from his bank count or send instruct to other assistant establishment. That realizes automatism management to running vehicle. Other assistant establishment mainly closed camera system of breaking vehicle, control railings, traffic instructions to the traffic equipment. (As red lights, green lights, yellow lights.)

III. The Design of Vehicle's Automatic Identify System

Vehicle's identify is the core technology to realize the system of electronic toll collection. But what's mean the vehicle's automatic identify system? It's the technology which can identify the vehicles passed without any action adopted by the driver or observer, when vehicles passing the

especial dot. It can be applied not only in highway's electronic toll collection system, but also in highway's transport such as navigation, especially in highway's transport, there is wide and latent applied foreground.

The process of vehicle's automatic identify is: when a vehicle passes the Read module in roadside, the dual-board transceiver being triggered, and launches codes can only show vehicle's identity, the retrieval unit antenna receives and transmit information to the Read module, so the deferent module to be checked for completeness and then transmitted to the computer system for data-processing and storage. The complex system with two-way communications also can transmit the data back to the vehicle by the antenna.

A. Several Major Vehicle's Identification Technologies

1. Optical and infrared AVI systems

This system uses a signs code labels similar to the bar code label which installed in a vehicle outside. The information from the vehicle identity is showed by a series of width or color changed lines, said that when the vehicles after capturing modules, and the different number and colors of light to be reflected on the Read module, which automatically analyzes the uniqueness-identification, the identity of the vehicle to show identification code information.

2. ICP AVI system

This system uses inductively coupling to transmit the data. The roadside Read module regards the conventional loop as antenna, which used to transmit signal to the vehicles from roadside Read module or opposition. The inductance dual-board transceiver uses simple loop or ferrite inspected haulm to be antenna, the antenna size is related with the wavelength of communication.

3. RF and microwave AVI systems

RF and microwave technology is the basis for some of automatic vehicle identification system. It uses microwave technology to achieve the transmission of data codes. Vehicle dual-board transceiver is capable of transmitting or receiving electric wave frequency range of 1000 Hz, trillion Hz and kilo mega Hz. The advantage of microwave system is that it can detect the data which transmitted by the rate much higher than the rate of ICP-ring detection, by this, it increases the volume of data the system can handle. For the antenna size is related with the wavelength used, the microwave transceiver is smaller than ICP transceiver in dimension.

4. SAW

SAW is the technical foundation for the identification system developed in recent years. A SAW systems is composed by a vehicle tag, one RF Read module and one signal processing module, the signal processing module is used to translate code labels and components to the information transmitted to computer.

5. Image Processing AVI System

The Image Processing AVI System is composed by the camera (CCD), image card and computer processing system. The image incepted by CCD, after APD conversion, will be transmitted to the computer system for image pretreatment and identification, the content of identification generally include license plate numbers, car models or colors.

Because electronic toll collection system requires very high reliability of communications, it requires almost 100% reliable and all-weather, at the same time, high data transmission rate is requires to ensure that the real-time identification.

Therefore, the only AVI technology of high communications ability, high reliability and high environmental adaptability can be used to the reality of the highway toll system. The application in world shows that the technologies used in highway electronic toll are still microwave and infrared technologies before certain technical issues yet to be fully resolved.

B. Comparison of the Infrared and Microwave Communications

Communication system usually distinct by the carrier frequency and the position of the electromagnetic spectrum, it is shown in Fig. 2.

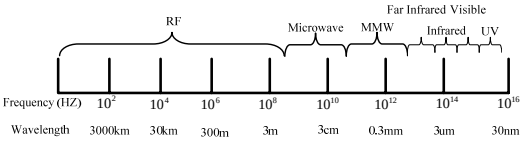

Fig. 2 Wave's frequency plan

For optical communication systems, the carrier wave is selected from optical wave bands, which includes infrared light, visible light and ultraviolet frequencies; the carrier wave in infrared communication system is selected from the infrared band.

For short-range wireless communication system, the use of infrared communication technology than microwave communication technology has significant advantages.

(1) Infrared communication bandwidth resource is rich, theoretically, optical wave band could have the available bandwidth is about 105 times the radio-frequency bandwidth; only the infrared band in 700-1500nm would have exceeded the available bandwidth 200THz.

(2) The use of frequency in infrared communication systems could do without permission, but the carrier frequency in microwave systems must obtain permission.

(3) Light wave has important significance to the security of the information transmitted for its good resistance to electromagnetic interference and high security.

(4) Infrared communication system is light intensity directly modulating light-emitting devices through current, is not a way to use high-frequency carrier. So it is relatively simple circuit design system.

Therefore, the system uses infrared wireless communication technology namely vehicles carrying electronic label to identify vehicles automatically.

C. The Theory and Design of ETC Infrared Communication

ETC infrared communication exchange the infrared wireless communication and information through the OBU

(Onboard unit) installed on vehicles and the RSU (Roadside unit) installed in a toll booth lane. Vehicle System and the base station antenna system both include optical antenna, infrared transmitters and infrared receivers, to ensure two-way communications to complete the exchange of information.

Communication between the OBU and the RSU divides into uplink and downlink, as shown in Fig. 3. When vehicles come into the communication region, the perception of vehicles is from roadside sensors, RSU issues asked signals through downlink, then OBU receives the inquired signals from RSU, and sends information through uplink to RSU, thereby, the two-way communication and data exchange between vehicle system station and base station system are completed, the base station system obtain vehicle identification information.

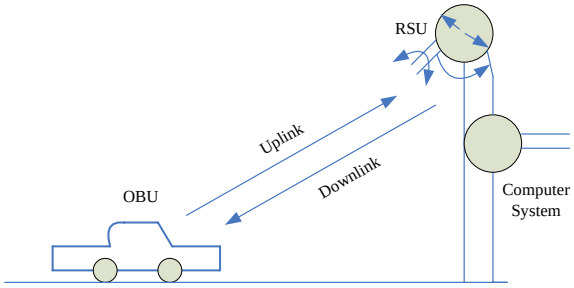

Fig. 3 ETC infrared communication link plan

1. RFID (The radio frequency identification) technology related to OBU

RFID has two kinds: fountainhead and no fountainhead electronic labels; active and passive electronic labels.

RFID refers to the use of radiofrequency identification signal to the identification of the object. ETC use RFID mainly for automatic vehicle identification (AVI, automatic vehicle identification), usually only 8~30m distance communications, 915MHZ,2.45GHZ and 5.8GHZ were used and researched internationally as such communication frequency. As with other frequency, 5.8GHZ has better data transmission rate, maintaining the same effective communication distance higher transmission power, the system carrier ratio and strong anti-disturbance, moreover, because many of the equipment manufacturers have the support system in the security and scalability on the character. So, the system adopts 5.8GHZ as the communication frequency.

Using RFID technology in ETC is mostly that OBU stored the relevant information related to the corresponding vehicle; any information transmitted by OBU has relevant information with its vehicle. OBU has two states, general, the entire circuit of OBU unit is at the static state, only the awakened circuit is all at work state, the electric current consumption is very low. When vehicles passing the region which covered by RSU antenna in the electronic toll collection, the circuit is awakened, then the whole circuit is at work state.

2. The components of OBU system

The components of OUB modular hardware is shown in Fig. 4.

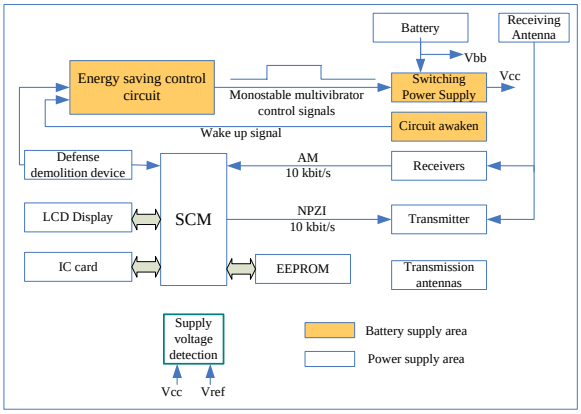

Fig. 4 The components of OUB modular hardware

SCM is the OBU processor module and the core of the number modules. Its function includes completed signal processing and control function of OBU system. Such as: 1. complete decoding function; 2. decoding the AM signal which received by incept machine; 3. special coded the emissive up-row data to meet the needs of real communication; 4. achieved various control functions.

3. OUB software functions

OUB software system should accomplish the following functions.

(1) Achieved application logic of ETC.

(2) Implemented the interface to frequency transceiver circuit; offered the transmitter NRZI encoding of 10Kbit/s rate and received 10Kbit/s rate AMD encoding signals and awaken signal from incepted machine to achieve the functions of NRZI encoding and AMD decode.

(3) Achieved the agreement of SDL.

(4) Achieved the function of reading attribute information.

(5) Achieved the function of anti-demolition.

(6) Achieved the function of saving energy.

4. The results of prototype for indoor and outdoor experimental

Done experiment for prototype system in indoor and outdoor. By the indoor experiment result analyzed, we can get these conclusions: when we come to the surrounding environment, the optical power received by receiver is proportional to the optical power launched by receiver. When the launching optical power is certain, if the receiver aims at the transmitter, then the optical power is proportional to the square of the distance. When the launching optical power is certain, if the receiver is at the transmitter emits axis line, the optical power received is proportional to the receive direction cosine. Under these experimental conditions, the bit error rate curves measured relatively coincide with the bit error rate curve from theoretical analysis. This shows that the conclusions analyzed are reasonable.

In the outdoor experiments, I tested the error rate of various conditions; the final results' analysis showed that the prototype system produced can communicate in gear under different weather conditions. So using infrared wireless communication technology to upgrade the existing ETC automatic toll system is feasible and it can reach the maximum data transmission of 4Mbps.

IV. The Realization of Highway's Electronic Toll Collection Simulation System

Since this system is at the stage of research, therefore, in this paper, I mainly studied its feasibility and practicality through the fashion of simulation system.

A. System Components

This simulation system is component of vehicle terminals, center control and banks. Its structure is showed as Fig. 5.

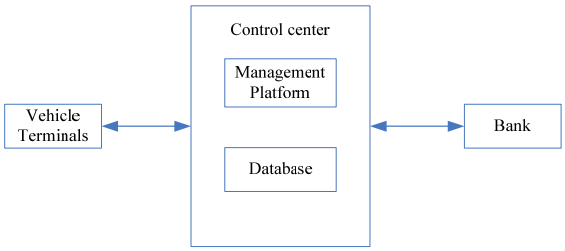

Fig. 5 The structure of manager system

1. Vehicle Terminals

Vehicle terminals are as a data collection terminal and its main function is collection positioning data. It is composed of GPS, positioning module, communicate network module and data stored module (mainly stored basic information of vehicle and IC account).

2. Center Control

Center control as data processing center is the core of the whole system. Its main function is completion the decision-making of system. It is composed of database sever and manager plat. Database main function are incepted the information of vehicle terminals and banks, appropriate treatment and send the result to the terminal unit.

3. Center Operation of Banks

The center operation of banks' function is simulated bank to charge. It accepts the vehicle owner bank account information which was sent form center control, charge and returns the result of charge to the center.

B. Logic Design of the System's Functions

The main function of the system divided into three categories.

1. Information gathering and communication network function

Information gathering prefers to gather the location data of mobile vehicle terminals, dictate response and identification information, and then transmit these to the center control. Center control handle and judgment the data, memory location information to the database, and make a decision whether need for charge. The control center can return the direct inquiries and notification to the vehicle terminals.

The main assignments are accomplishing communication network function, information gathering function and information processing function.

2. Billing and vehicle fee function

a) Vehicle billing function

Control center judges the vehicle location data received, prepare it with the information network in database. After judging whether a vehicle fee, and whether charge, and take the amount of payments the vehicle should pay from the charge rates in the database.

b) Vehicle fee function

Control center will transmit the compared amount of payments the vehicle should pay from the database and the owners' accounts together to banks. Bank simulation receives the accounts and charges, and judge whether the charges are successful. Results issued to the control center, the control center sent inform to the vehicle terminals based on the results of fee.

3. Systems and vehicle management function

a) Vehicle management function

Control center can inquiries, statistics, print statements the registrant vehicles' data or information (including the number of vehicles, number plates, models, colors, drivers, photographs and so on). It also can registries, deletes, update the information of vehicle terminals.

b) Database management function

It can manage and maintain all types of data in system, to ensure the safe and reliable operation. It also can backup, restore and optimize the database.

C. Operating Environment of Terminal Simulation

Because the vehicle simulation terminal is programmed with Visual C++6.0, the same as control center software, it can run on any operation system above Windows98.

In order to a more realistic simulation of the data transmission, the entire system hung an Internet when data receiving instead only testing in LAN. Through the wide area network, it connects to the system control center software which links to ADSL. Then this system is closer to the actual operating environment, in which the vehicle internal equipment connected to the system control center software through Internet. Through that, the research findings are closer to the applying environment and more convincing.

V. Conclusion

This paper mainly reviewed the research and development work on the highway parking system. Using infrared wireless communication realized the core technology of ETC; from

theoretical and experimental analysis, designed and realized outdoor prototype system for short-range wireless infrared communication, and through software simulated the vehicle terminals' integrate highway parking process. And it also realized the data exchange between terminal software and system control center; completed the business functions and system requirements of logical design phase; achieved the desired objectives.

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