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APPLICATION OF COMMUNICATION TECHNOLOGY IN MALAYSIA TOLLING SYSTEM

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9.1 INTRODUCTION

The Malaysian expressway network can be considered the best expressway network in Southeast Asia and third in Asia after Japan and China [1]. The total length is 1,192 kilometres (740 miles) [1]. All Malaysian toll expressways are managed in the Build-Operate-Transfer (BOT) system [1] .Every expressway and highway in Malaysia has a toll system, which are either a closed toll system or open toll system and known as Electronic Toll Collection System (ETC) [2]. Electronic toll collection (ETC), an adaptation of military "identification friend or foe" technology, aims to eliminate the delay on toll roads [2]. It is a technological implementation of a road pricing concept [2]. It determines whether the cars passing are enrolled in the program, alerts enforcers for those that are not, and electronically debits the accounts of registered car owners without requiring them to stop [2].The first ETC system was implemented along 22km expressways in 1995 and as of today, the whole stretch of 1,459 km expressways are equipped with a single ETC system allowing for full interoperable [3]. The first ETC system was Technology implemented is 2.45GHz microwave in 1994 and another highway operator introduced the same technology in 1997 [3]. The system was further enhanced in 2001 to meet the international standard of 5.8GHz [3].

A contactless smartcard ETC was introduced in 1997 and the system was enhanced further with the introduction of twopiece

On-Board-Unit for ETC in 1998 [3]. This system later adopted as the 'single ETC' system for Malaysia [3].

9.2 THE COMPOSITION AND PRINCIPLE OF ETC SYSTEM

Wireless communication and information change can be done with ETC systems by the device fixed in the vehicle and road head device which was fixed in the toll station's roadway. [4]. It composes by automatic vehicle identification system, centre control system and other ancillary facilities [4].

The system of automatic identification vehicle is composed by on board unit, road side unit, loop sensor and other components and the centre control system is consisted of large database and the information of enrolled vehicles and users [4].

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 will exchange [4]. Identify vehicle information will fetch by centre control system like as car's ID and car's module and after that it will compare these information to the database [4].

According to situation, it controls the centre manager system do different operation [4]. Such as computer charge manager system deducts these travelling expenses from his bank count or send instruct to other assistant establishment [4]. 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) [4].

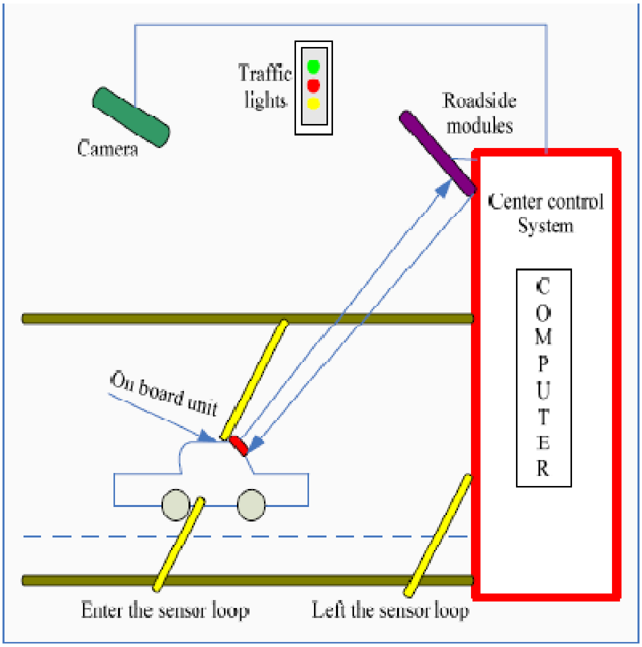

Figure 9.1 The principle of ETC system

9.3 DESIGN OF VEHICLE'S AUTOMATIC IDENTIFICATION SYSTEM

Vehicle's identify is the core technology to realize the system of electronic toll collection [4]. 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 [4]. 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 [4]. 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 [4]. The complex system with twoway communications also can transmit the data back to the vehicle by the antenna [4].There are several major vehicles' identification technologies like Optical and infrared AVI systems, ICP AVI system, RF and microwave AVI systems, SAW and Image Processing AVI System [4].

9.3.1 Optical and infrared AVI systems

This system uses a signs code labels similar to the bar code label which installed in a vehicle outside [4]. The information from the vehicle identity is showed by a series of width or colour changed lines, said that when the vehicles after capturing modules, and the different number and colours of light to be reflected on the Read module, which automatically analyzes the uniquenessidentification, the identity of the vehicle to show identification code information [4].

9.3.2 ICP AVI system

This system uses inductively coupling to transmit the data [4].The roadside Read module regards the conventional loop as antenna, which used to transmit signal to the vehicles from roadside Read module or opposition [4]. 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 [4].

9.3.3 RF and microwave AVI systems

RF and microwave technology is the basis for some of automatic vehicle identification system [4]. It uses microwave technology to achieve the transmission of data codes [4]. Vehicle dual-board transceiver is capable of transmitting or receiving electric wave frequency range of 1000 Hz, trillion Hz and kilo mega Hz [4].

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 [4]. For the antenna size is related with the wavelength used, the microwave transceiver is smaller than ICP transceiver in dimension [4].

9.3.4 SAW

SAW is the technical foundation for the identification system developed in recent years [4]. 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 [4].

9.3.5 Image Processing AVI System

The Image Processing AVI System is composed by the camera (CCD), image card and computer processing system [4]. The image incepted by CCD, after APD conversion, will be transmitted to the computer system for image pre-treatment and identification, the content of identification generally include license plate numbers, car models or colours [4]. 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 [4]. There is many advantages using Electronic Toll Collection (ETC) unlike other ITS technology, ETC is not dependent on the implementation of new, advanced technical systems or an integrated infrastructure to be successful [3].

9.4 SATELLITE TECHNOLOGY IN ETC

The pioneering endeavour by Toll Collect based on GPS/GSM (Global Positioning System/ Global system for Mobile Communication) for Road User Charging Systems, is the awakening for a new era of satellite technology in toll collection [5]. The market for Road User Charging Systems has been dominated by ETC (Electronic Tolling Collection System) for a prolonged timeline. The most renowned technologies for charging road users range from manual, automatic to DSRC based electronic toll collection [5]. The Dedicated Short Range Communication (DSRC) frequency is a dominant technology used for electronic toll collection systems [5]. The system although dominant, experienced shortcomings of incurring high investment costs and land space requirements to set up beacons on every entry and exit point of a toll road. The DSRC technology also renders difficulties of having a huge infrastructure requirement in case of distance based road user charging for longer routes. Toll Collect's new satellitebased ETC, which entails the satellite based tolling could be seen as a feasible solution for the challenge in reducing these infrastructural costs. This new satellite-based ETC by Toll Collect is used for vehicle-tracking [5]. Toll Collect identifies the exact location of the vehicle and uses mobile communication technology for computation of toll charges [5].

The new satellite-based ETC has been a pedestal to Toll Collect's success stories. Frost & Sullivan foresees a major change in the market dynamics of toll collection in Europe [5]. This system will most likely define a paradigm shift from the existing technology throughout Europe, reflecting on Toll Collect's innovative accomplishment and contribution to the Road Transportation Industry.

9.5 ETC DEVELOPMENT IN MALAYSIA

9.5.1 Advantages Using ETC

There is many advantages using Electronic Toll Collection (ETC) unlike other ITS technology, ETC is not dependent on the implementation of new, advanced technical systems or an integrated infrastructure to be successful [3]. However, the ETC will benefit greatly from the development advance technology such as smartcard and wireless telecommunication to enhance its functionality. ETC also is one of the most successful implementation in the whole range of Intelligent Transportation Systems (ITS) applications and benefits of ETC implementation is to eliminate congestions on existing and new toll highway and to minimize fraud, providing user convenience and at the same time enhancing operational efficiency for toll operators [3]. For Malaysia, various ITS applications such as Tolling System and Traffic Management System have been developed several times and implemented to enhance operational efficiency [3]. Dedicated ETC lanes can process toll transaction faster than manual system, thus ETC lanes can improve the throughput of traffic flow.

9.5.2 The Introductory Period (1994-2001)

For beginning, in 1994 the journey towards achieving 'single and interoperable ETC' is started and afterward by July 2004, the systems were implemented nationwide [3]. During the earlier stage of ETC Development in Malaysia, various system and new technology were introduced [3]. The toll highway operators were actively involved in ETC development in Malaysia as they realized the needs to reduce cost of toll collection, capital investment savings, fraud elimination, faster journey time, increased fuel, less congestion and reduce pollution [3]. In 1994, the first ETC system in Malaysia was introduced by the North-South Expressway (NSE) based on 2.45 GHz microwave technology and marketed as *PLUSTag*, covering only the length of 22.0 km from whole 848 kmhighway [3].

Contactless smartcard based ETC technology was introduced in 1995 to replace discount vouchers to users , upon completion of the Penang Bridge linking the Peninsular Malaysia with Penang Island in the northern area [3]. Shah Alam Highway (KESAS) introduced another ETC system in 1997 based on 2.45

GHz and named as KESASTag. Cheras- Kajang Highway was the first to introduced 5.8 GHz microwave in Malaysia [3]. They also brand their product as SagaTag in 2000 [3]. The system at KESAS was later upgraded to 5.8 GHz in 2001[3]. That was to ensure compatibility and interoperability with ExpressTag introduced by LDP and SPRINT Highways [3]. In the same year, a consortium (Rangkaian Segar Sdn Bhd – RSSB); consists of highway concession, a financial institution and LRT operator introduced a 'Common ETC' based on pre-paid e-purse system [3].

The system is known as the Touch 'n Go Electronic Payment System (EPS) [3]. It was operated by Rangkaian Segar Sdn Bhd (RSSB) as the Service Provider [3]. The Touch 'n Go system based on the contactless Smartcard was first installed at East-West Link Highway and expanded to PLUS, Penang Bridge and Malaysia-Singapore Second Crossing (Linkedua) in 1998 [3]. Other highway concessions started adopting the Touch 'n Go system from August 2000 [3]. With the introduction of Infrared DSRC ETC technology in 1998, the system was further enhanced to non-stop ETC [3]. The tag is a two-piece on-board unit where Infrared Technology is used for DSRC communication and Touch 'n Go card for payment of the transportation charges [3]. The chronological events during the introductory stage are as follows:

Table 9.1 Chronological Events of ETC System in Malaysia

Year	ETC System Introduced	Operator	Highway	Technology
1994	The first ETC system was Introduced in Malaysia (PLUSTag)	PLUS	North-Klang Valley Expressway (NKVE)	2.4GHz Microwave
1995	The first pre-paid contactless Smartcard was introduced for ETC (BridgeKAD)	Penang Bridge	Penang Bridge	Contactless Smartcard Technology
1997	Touch 'n Go EPS introduced For ETC application (Touch 'n Go)	RSSB	Metramac	Contactless Smartcard Technology
1998	RSSB introduced Infrared On-Board-Unit ETC system (SmartTAG)	RSSB	Penang Bridge, NSE An some city Expressways	Infrared Technology (Two-piece Tag)
2000	The fist 5.8 GHz Microwave ETC was introduced in Malaysia (SAGATag)	Grand Saga	Cheras-Kajang Highway	5.8GHz Microwave Technology
2001	The inter-operable Microwave ETC between KESAS, SPRINT and LDP Highways (ExpressTAG)	Gamuda	KESAS,LDP and SPRINT Expressways	5.8GHz Microwave Technology
2004 onwards	Single ETC system (Touch 'n Go and SmartTAG)	RSSB	All Toll Highway in Malaysia	Infrared Technology (Two-piece Tag)

During the above introductory period, there are four (4) local Toll System Integrators that emerged to provide ETC for 18 toll highway operators in Malaysia [3]. Malaysian Banks also started providing facilities for ETC pre-paid reloading through Automated Teller Machine (ATM) and convenience of credit card auto-reload [3].

9.5.3 The Single ETC: Consolidation and Standardization Period (2003 – 2005)

Malaysia already has two different ETC technology i.e. Infrared and Microwave by the end of the introductory period (2001) [3]. Due to this, public need to have three (3) ETC devices (SmartTAG, ExpressTag and SagaTag) to enable them to use the non-stop ETC for payment of toll charges within Kuala Lumpur city [3]. There was a unanimous decision amongst the toll highway concession companies on the requirement for a national standard for ETC Systems to streamline deployment and to ensure interoperability after a survey that conducted by MHA in 2001 [3]. There are certain requirements for the successful deployment of ETC systems in Malaysia can be listed as follows:

- Has ability to operate both the open and closed toll systems [3].
- The systems that will build must support all vehicle types (presently it is mostly supporting only Class 1 vehicles only) [3].
- Before the toll concessionaires hand over the toll collection responsibility to the clearinghouse, the ETC systems must have high security, reliability and accuracy [3].
- The ETC systems that develop must has interoperability and also allow users a smooth passage through all the toll highways regardless of the toll operators [3].

- The systems affordable to allow maximum penetration of the market by systems user and public acceptance of the systems [3].
- Has multi vendor or suppliers of the ETC devices [3].

Based on the above requirements, for single electronic toll collection system for all toll highway in Malaysia, the Government endorsed the Touch ‘n Go and SmartTAG ETC systems as the most suitable solution at that time [3].

Malaysia has achieved nation-wide interoperability of ETC system with the adoption of a single ETC system for the existing 18 toll concessions companies in operation [3]. Malaysia in many ways is ahead of many countries in the world on the implementation of ETC. Motorists have greatly benefited from the single interoperable system irrespective of which highway networks they use. Highway companies on the other hand, have gained from the reduced duplication of tasks and resources, toll collection efficiencies have improved and operational cost savings have been realized [3]. At June 2006, the average ETC penetration rate nationwide is 37% and 50% for Klang Valley toll highways and it conclude that the ETC penetration has been growing steadily [3].

9.5.4. The Future: Multi Lane Free Flow ETC

To evaluate prospects of Multi-Lane Free Flow (MLFF) is the next step for Malaysia where it promises reduction in congestion at toll plazas, environmental friendly and increase road safety [3]. Multi-Lane free flow (MLFF) system is an electronic tolling system that used in many expressway networks worldwide [3]. Such countries like Australia, USA, Chile and Canada already extensively implement full electronic toll payment [3]. In May 2005, MLFF working committees comprise of officials from MOW, MHA, toll concessionaire and RSSB was established toward this objective [3].

For successful implementation of MLFF in Malaysia, a variety of structural issues and operating challenges need to be reviewed and considered, establish proper operating and enforcement structures, efficient and adequate supporting systems with proper contractual and legal framework. The establishment of MLFF has proven to stimulate substantial multiplier effects and advantages to all facets of the society, nation's economy and the governments. The primary advantages of MLFF including improve traffic throughputs that will reduce travel times for road users, enhance savings to business community through fuel savings, vehicle's wear and tear and travel time certainty [3]. Its implementation generates significant long term economic activities, growth and employment [3].

Migrating from the current ETC to a full-scale multi-lane free flow is the key challenges of MLFF implementation in Malaysia [3]. The key issues that must be face will be mostly related to legislative and contractual, public education and acceptance, and MLFF operations, technical and maintenance management [3]. The issues and challenges that need to be addressed by all relevant parties are enforcement issue, funding for MLFF infrastructure and public acceptance to ensure smooth and successful implementation of multi lane free flow in Malaysia [3].

9.6 CONCLUSION

Electronic Toll Collection (ETC) is the application of communication technology in tolling system in many countries especially in Malaysia. ETC also is one of the most successful implementation in the whole range of Intelligent Transportation Systems (ITS) applications. There is many advantages using Electronic Toll Collection (ETC) unlike other ITS technology, ETC is not dependent on the implementation of new, advanced technical systems or an integrated infrastructure to be successful. For Malaysia, various ITS applications such as Tolling System and Traffic Management System have been developed several times and implemented to enhance operational efficiency. Dedicated

ETC lanes can process toll transaction faster than manual system, thus ETC lanes can improve the throughput of traffic flow. Development of ETC system in Malaysia already started in 1994 and by July 2004, the systems were implemented nationwide. Contactless smartcard based ETC technology was introduced in 1995 to replace discount vouchers to users. Malaysia already has two different ETC technology i.e. Infrared and Microwave by the end of the introductory period (2001). Malaysia also has achieved nation-wide interoperability of ETC system for the existing 18 toll concessions companies with the adoption of a single ETC system. Malaysia in many ways is ahead of many countries on the implementation of ETC. Multi-Lane Free Flow (MLFF) is the next step for Malaysia to evaluate where it promises reduction in congestion at toll plazas, environmental friendly and increase road safety. Migrating from the current ETC to a full-scale multi-lane free flow is the key challenges of MLFF implementation in Malaysia. We believe that MLFF would be reality in Malaysia in the near future.

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