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Electronic toll collection technologies: A state of art review

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Abstract— This work covers the state of art of various existing electronic toll collection (ETC) technologies. Also, the present study covers the technical and economical aspects associated with these technologies. All technologies understudy are reviewed in context of their suitability for Indian roads. In this direction, the pros and cons are discussed and compared to determine the conflict in tradeoffs among these technologies prior to implementation in India.

Keywords— DSRC, ETC, VPS, GIS, ISRC, ANPR

I. Introduction

India is the fastest growing economy in the world. This leads to exponential hike in technology usage. It is obvious to have enhancement in domestic problems with technological growth of an economy. In a developing country like India, these problems are needed to be addressed quickly. But, it requires comprehensive investigation of all past, present and future technological, social, economical and environmental aspects of a country. Parallelly, a careful cognizance of distinct resources such as infrastructure, psychology of the people and many other socio-economic factors is warranted. Present manuscript addresses one such problem of adoption as well as implementation of advanced electronic toll collection (ETC) technologies in India. In present study, we have considered the existing ETC technologies in the world. The most promising ETC technologies in the world are based on 1) DSRC (dedicated short range communication) which covers barcode and RFID (radio frequency identification) [1-5], 2) Video tolling that includes ANPR (automatic number plate reader) [6-9], 3) global positioning system (GPS) or geographic information system (GIS) or vehicle positioning system (VPS) and 4) Infrared short range communication (ISRC) based on calm active infrared [10-15].

II. Technologies

A. *Barcode-based ETC*

Barcode-based ETC is a sub category under DSRC. In this a bar-coded sticker is attached to the vehicle and read by a laser scanner when it passes through the toll plaza. Fig. 1 illustrates working of a typical DSRC system for electronic tolling. It is the simplest as well as oldest technology. It is widely used in various applications such as in library for managing book record, shopping plazas to take an account of sale and purchase, food industry to store food details and many more. Despite of these all it also has several drawbacks in order to be used for toll collection system such as lack of reliability (as can be easily imitated), less accuracy in bad weather, lack of flexibility, slow data read rate, less storage information and easy to be theft.

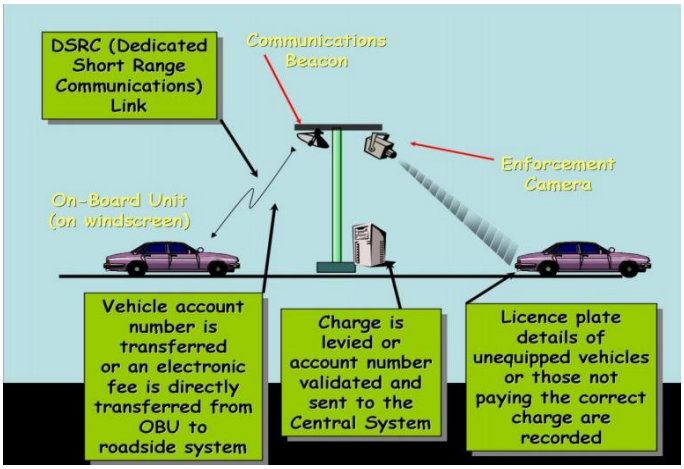

Fig.1 DSRC system for electronic tolling [19]

B. RFID-based ETC

Second technology is RFID-based ETC system [10, 12], which has an IVU (In-vehicle unit) installed on the front windshield of the vehicle (shown in Fig. 2). This IVU contains a cash card for payment of road tax. At toll plaza, this is read by the RFID frequency reader or antenna. It can be either prepaid or postpaid, with gate or without gate. Fig. 1.3 illustrates working of RFID-based ETC system. It contains more information as compared to barcode, has faster reading rate, tough to be fraudulent and also comparatively more reliable. As the number of features increases we have to compromise with the cost, simplicity and ease to use. It is also observed that sometimes it show the problem of interference among frequency of devices (mobile phones, other IVU, walkie-talkies, FM radio or other electronic gadgets) in vicinity of the toll plaza or passing vehicles. Angle of installation and alignment plays an important role for reliability and high accuracy of these systems. Fig.3 provides a brief idea about working mechanism of RFID-based ETC technology.

C. ANPR

Third important technology is ANPR [12, 16]. It utilizes a stationary camera to record and identify the number plate of vehicles passing through toll plaza. The identified license numbers are matched in the database (connected with transport office) and toll is deducted. If the recorded number is not read properly or not found in the records, it issues an enforcement violation alarm to the alert the authorities. In this way, it simultaneously solves two objectives; identification of vehicle for deduction of toll tax and issuing/recording violation enforcement alert. The Indian government has started issuing "high security number plates", which is tough to be falsified. Thus this technology will also be helpful to detect the stolen vehicles and vehicles with fake number plates. It also has constraints of high cost and reduced accuracy under tempestuous environment conditions.

Fig.2 IVU (In-vehicle unit) [2]

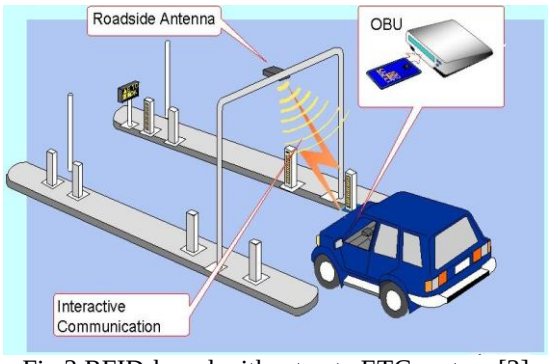

Fig.3 RFID-based without gate ETC system [3]

Fig. 4 explains working and recording via ANPR.

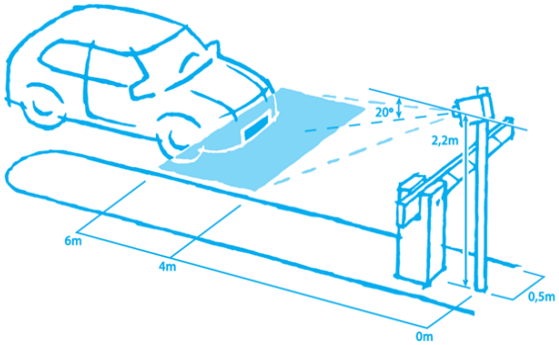

Fig.4 Working of ANPR [5]

D. Calm active infrared

Calm active infrared [17-19] is a relatively new technology. It is similar to RFID system, the only difference is that it has an active infrared unit installed on vehicle which contains all the information. In comparison to RFID, it has a faster data reading rate, reliability, accuracy, efficiency and it works well in all environment conditions. It also comes over the problem of interference. Lack of interoperability, vendor support and high cost are the roadblocks in usage of this technology. Apart from these, it is still under research and many other aspects need to be studied yet.

E. VPS-technique

Fifth technology in this list is VPS. VPS-technique [2, 20, 21] consists of worldwide satellite navigation system incorporation with a communication mechanism (Fig.5). It works with the help of a global positioning system (GPS) unit installed on vehicle attached to an on board unit (OBU) , which stores the coordinates of the vehicle and send the transaction information to the toll authorities via GSM (global system mobile communication). This system is highly reliable, accurate and efficient. The efficiency of this system is not affected by environmental conditions. It provides a payment option only for the distance travelled and is highly flexible in generating the corresponding payment details. It can also be used by the police petrol for highway surveillance and theft prevention of automobile. The associated shortcomings for this system are its excessively high installation, running and maintenance cost, careful handling, requirement of extra power and other accessories.

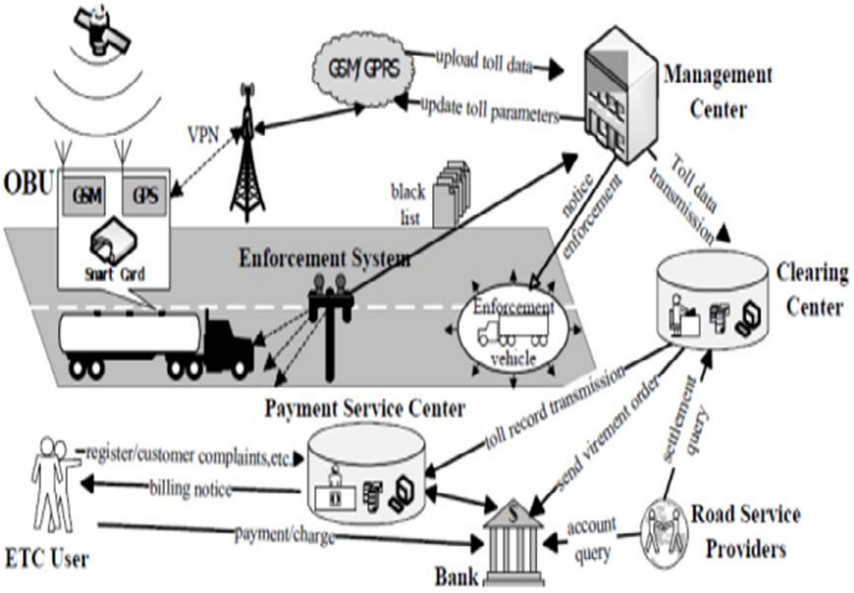

Fig. 5 Complex network for GPS-based ETC system [5]

III. Discussion

Present study has made it very clear that there are no clear trade-offs among the above mentioned technologies. Due to this, it becomes an onerous task to move further to decide the best option among the existing ones or to develop a newer technology. In such a state of ambiguity when one is not even able to choose the best among the existing alternative, there is no space for the question of adopting a hybrid technology. It also demotivate the policy makers to adopt newer advanced technologies as a single wrong decision can bring up loads of problems for coming generations with huge wastage of money and time. Therefore, it becomes essential to predict the best solution in terms of best alternative for such problems using a highly subjective decision making technique.

In this context, we aim to figure out a solution by aid of multiple attribute decision making (MADM) techniques. A variety of methods are reported under MADM category. These methods include simple additive weighting (SAW), analytic hierarchy process (AHP) [22], graph theory and matrix approach (GTMA) [23], VlseKriterijumska Optimisacija I Kompromisno Resenje (VIKOR) [24], technique for order preference by similarity to ideal solution (TOPSIS) [25] and many others. These have been successfully applied to various fields such as manufacturing processes [26], supply chain management [27], social science decisions [28], financial decisions [29] and engineering problems [30, 31]. MADM models are used to select best alternative from the large number of alternatives for a set of selection criteria. Moreover, these also tell about the degree of closeness in terms of rank index. The above mentioned MADM approaches work on crisp values of attributes. However, in case of selection of advanced technologies, most of the attributes/parameters depend on views of various decision makers (such as user, operators, government, distributors, technical and economy experts etc.). There are no clear boundaries among the views of these decision makers. The present study is one of the first efforts to pin point the issues concerned with selection of optimal ETC system in India. In future we hope to subjectively study and figure out the answer to the question raised by us in the present study.

IV. Conclusions

To recapitulate it all, we have considered five very popular electronic toll collection (ETC) technologies for Indian scenario. We found that due to diversity in Indian geographical, social and political views it is quite difficult to have a single ETC system throughout India. However, as per Indian scenario a optimal technology can be selected using MADM techniques. Prior to implementation of such optimally identified technique very sincere efforts are required to modify it according to the needs of local people and government. Also, first of all it is crucial to identify the area wise prime parameters that can influence selection as well as implementation of any such technology.

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