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Smart Toll Collection System for Bangladesh

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Abstract: This paper focuses on a smart toll collection (STCS) system based on non-contact BLE (Bluetooth low energy) technology specially designed for Bangladesh. A lots of river bridges, flyovers and Asian highways passes all over the Bangladesh. Governments need to collect the toll (a charge payable to use a bridge or road) from drivers/passengers who are using those bridges, flyovers and highways, for further development of the country. Two types of toll collection system, such as manual and computerized, exits in Bangladesh. Both system requires human operator for toll collection, which is more or less time consuming process. With this respect, a smart (fully automated) toll collection system is proposed throughout this paper. The conceptual design along with prototype implementation are elaborated in this paper.

Keywords: Smart toll collection, BLE, Beacon, Intelligent transportation system.

1. INTRODUCTION

Everyday thousands of drivers/consumers pass through toll booths for paying toll fees. In Bangladesh, two types of toll collection system, such as manual and computerized, are available. Both toll collection system shown in Figure 1, collect toll fees by exchanging coin or cash, from drivers/consumers by hand while they are crossing the toll plaza gate. The main difference between manual and computerized toll collection system is, manual system uses hand written bill (invoice/receipt) for collecting money while computer generated bill is used by computerized system. While paying the tax/fees, drivers need to wait in a long queue for a long time. Overall, the manual payment system is too much time consuming. Besides, at the time of waiting, vehicles also face wastage of oil. Another most serious problem with respect to Bangladesh is corruption. Manual system is more corrupted than computerized system. To resolve this phenomenon, an automated toll collecting system is presented in this paper.

2. RELATED WORKS

The ATC (Automated Toll Collection) system is currently being used throughout the world. Various states of U.S.A already implemented Automated Toll Collection system namely E-Z Pass [1]. Other developed and developing countries such as Italy, Netherland, Japan. Malaysia, Canada, Singapore, Poland, Canada, China, India and many others applied ATC system for collecting toll fees. A brief discussion of the applied ATC systems are given bellow:

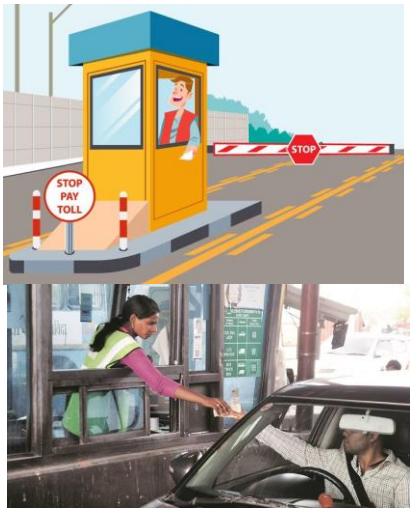

Figure 1. Traditional Toll Collection System of Bangladesh (photo: google).

A. Canada

The Electronic Toll Collection system of Canada is one of most sophisticated toll roads in the world. This toll collection system is known as 407-Express Toll Route shortly ETR [2] shown in Figure 2. The entrance and exit points of this toll collection system are occupied with gantries.

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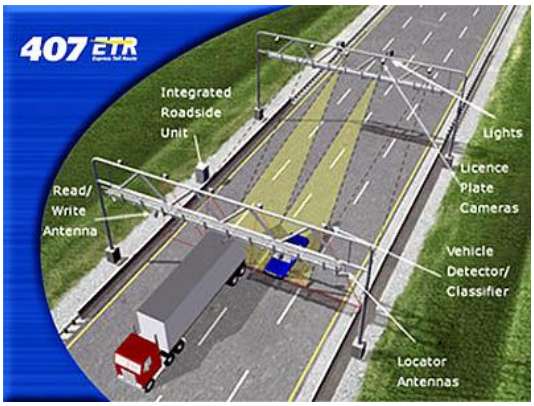

Figure 2. Electronic toll collection system of Canada (photo: google)

The OCR (Optical Character Reader) based cameras are used to photograph license plate numbers of vehicles, while they are passing through the road. The vehicles owner identification is done by matching the registered license plate number with license number database. Additionally, the system uses two laser beam scanners (mounted with gantries) for detecting the type of vehicles passing through the gantries. The system generates paper based invoice for collecting the toll fees.

The paper based toll receipt/invoice will then be sent to the registered address of the vehicle owners for collection. However, the implementation of this toll collection system requires high infrastructure cost [3].

B. Poland

The University of Technology in Warsaw and Dublin along with Poland Motor Transport Institute jointly proposed the Automated Toll Collection system in Poland [4]. The Automated Toll Collection system in Poland known as National Automatic Toll Collection System (NATCS) shown in Figure 3. It consists of onboard units (OBU) for vehicles, control gates (entry gate) and the National Automatic Toll Collection Center (NATCC). The combination of Global Positioning System (GPS) along with Global System for Mobile Communications (GSM) used by NATCS. The Onboard unit and GPS technology's technology together determined the distance that have been driven, calculate the toll fees by using predefined algorithm, and then transmit the information to the NATCS central server. In order to identify the license plate numbers of vehicles, the system uses high resolution cameras and digital short range communication (DSRC) detection equipment, which are mounted on control gate. The implementation cost of this toll collection system is very high due to its technical specifications.

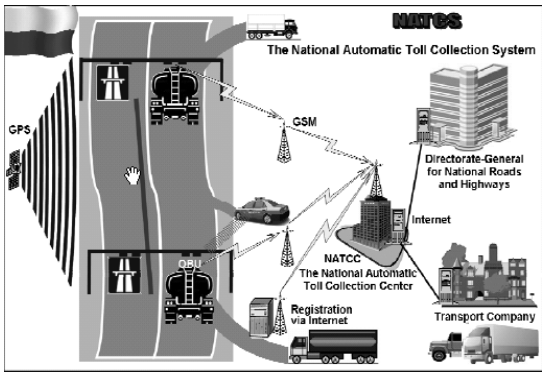

Figure 3. Poland's ATC System (photo: Google).

C. Philippines

In August 2000 Automated toll collection system namely E-PASS [5] has been placed at the South Luzon Expressway in Philippines. Radio Frequency based technology is used by E-PASS system. An electronic tag/transponder is placed in front of the rear view mirror of the vehicles. When vehicle enters the toll booth, the tag is recognized by the receiver, automatically identifying the owner's account and deducting the toll tax from the account. A SMS based bill collection receipt has been sent to the owner as well.

Figure 4. Italian toll collection system (photo: google)

D. Italy

The automated toll collection system of Italy is little bit different. The brand name of Automated toll collection company is TELEPASS [6], which is operated by Autostrade per l'Italia S.p.A. TELEPASS was introduced in 1989. It consists of onboard unit (OBU), which uses NFC (Near Field Communication) technology. The OBU unit transmit a signal which is detected by receiver of toll plaza. After Identifying the vehicle's owner by verifying the transmitted signal from OBU's unit, the toll amount is deducted from owner's account automatically. The TELEPASS OBU unit is elaborated in Figure 4.

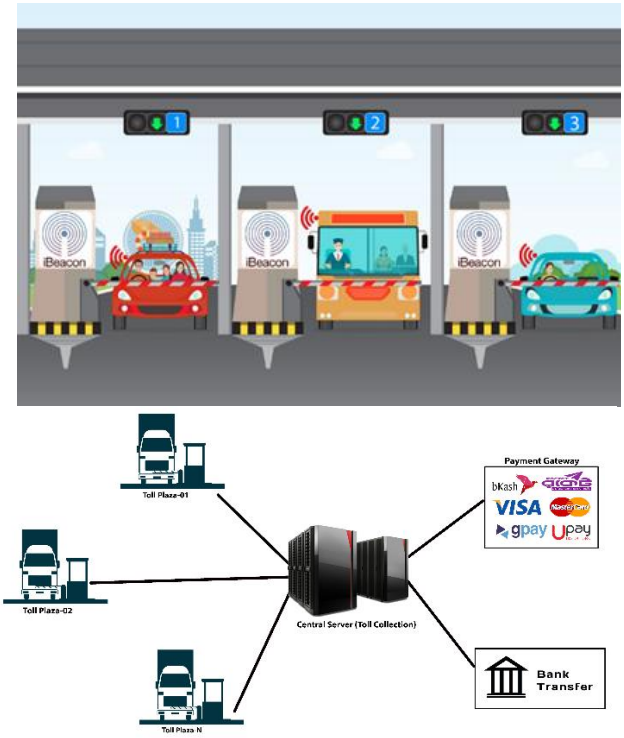

Figure 5. Proposed BLE (Beacon) based Smart Toll Collection System (photo: author).

3. PROPOSED TOLL COLLECTION SYSTEM

This paper mainly focused on smart/automated toll deduction system for hassle free toll collection. The necessary in vehicle device (beacon) is mandatory for identifying the vehicle's payment account information. The toll plaza occupied with single board computer with Internet access, which is responsible for recognizing the vehicle based on their transmitted signal. After that the toll plaza (a single board computer) sends the vehicle identification with deduction request from owner account to the central server. The central server deducts the amount and send the confirmation to the plaza. The toll plaza opened door after getting the confirmation. A payment confirmation (after a successful transaction) SMS (short messing service) will be sent to the owner for reference receipt.

A. Tools

The tools that are used for designing this system are onboard unit (beacon), Bluetooth receiver, single board computer with Internet connectivity, central toll collection server etc.

B. Design

BLE (beacon) tag can be installed on the windshield of the vehicles. Figure 5 gives a conceptual design of smart toll collection system based on BLE technology. The BLE reader mounted on toll plaza (BLE receiver device) receives data from the tag which placed on the vehicle. Reader device is placed on the middle of toll deduction gate and it is directly connected to the Central Server (Toll collection database). The central server is responsible for collecting money from vehicle's owner's account.

C. Middleware device/software

Middleware sits in the middle of the data flow of information between the toll plaza, beacon receiver and backend database of toll collection server. The middleware device is directly connected to beacon receiver which placed on the gate of toll plaza via serial communication protocol. All the toll collection plaza is connected with toll collection server and central database via wide area network (WAN). The whole record of toll deduction will be stored at the toll collection server and monthly transaction will be sent to the consumer/government from the toll collection server.

D. User Information

Since, Customers bank account/payment information is associated with their vehicle identification Bluetooth tag. Additional information such as vehicle types and registration number is also included with this tag. Every time vehicle passed from the toll plaza beacon receiver collect relevant information from the tag/beacon and the toll fee is automatically deducted from electronic payment systems.

Vehicle's owner can easily update or access their account information via website, interactive voice response (IVR) system or visiting customer care points, by providing proper user credentials such as account number and password. The user credentials are included on their statement. Users/customers will receive their accounts statement on weekly or monthly basis depending on their choice. Account statement contains record of total balance, opening date of account and all transaction information in details. If consumer doesn't deposit credit to his/her account for a long time or low balance is remain then the customer will receive a notification of low balance by email or as a SMS.

4. OPERATIONS

In proposed smart toll collection system a vehicle arrive in toll plaza the receiver device collect the transmitted signal from on-vehicle device (beacon). Beacon has a unique identifier universally unique identifier (UUID) [7]. UUID is used for identifying the vehicles as well as vehicle owner's account information/payment information. The computer of toll plaza sends owner's information to central server database. The central server or toll collection server checks the account information for validity. After performing the validation check the central deduct the toll fees from the account and vehicle will pass the toll plaza. A successful transaction short message SMS also sends to driver/owner that how much tax is paid. A confirmation

message also shown in the display board located in front of the plaza. Passing of vehicle throughout the plaza and transaction of toll fess is finalized within a short time.

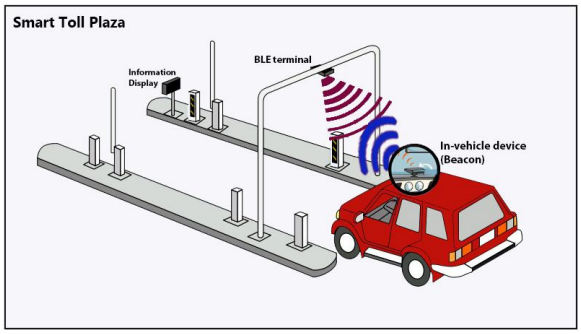

Figure 6. Our proposed toll deduction system working flow/ data flow diagram (photo: author).

The central server/toll collection server stores all details information of transaction, which contains location of toll plaza, time, date, and total payment amount. If the account balance is low, then the system generates indication for low balance. Figure 6 highlights the above discussed toll collection procedures.

5. COMPARISON

The difference between proposed toll collection system with other toll collection systems are represented in Table-1. The power consumption of BLE technology is very low which provides the opportunity to build environment friendly devices/ systems. A power level consumption graph is depicted in Figure 7.

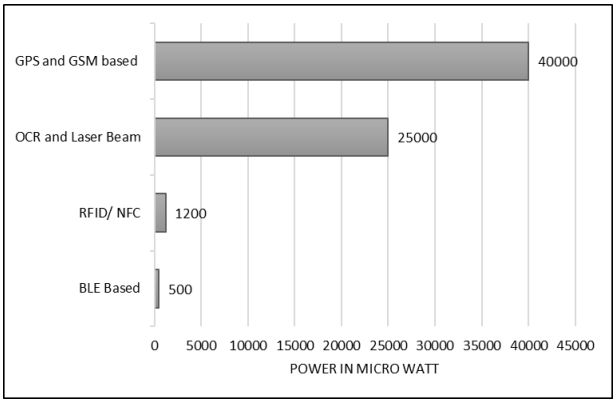

Figure 7. Power consumtion charts (per 100 operations).

6. CONCLUSION

Smart/automated toll collection system is the hassle free way for collecting toll fess. The innovation of BLE (Bluetooth Low Energy) based toll collection system is much more cost effective compared to other NFC based system. Additionally, the system is environment friendly, because of its power consumption nature (very low). The application domain of this system is not bounded with toll collection, there is a huge opportunity to extend this system for others application such as smart parking management system and many others as well. Integration of BLE based speed detection system is left for future work.

7. APPENDIX

A. Beacons (Bluethooth proximity device)

Beacons/Bluetooth beacons are cheapest and lightweight, micro-location based embedded devices able to send radio frequency signals and alert nearby Bluetooth devices about their occurrence and spread data/information. Mobile devices/smart phones can detention their signals. Those devices also measured the received signal strength for determining the distance between them (mobile devices and beacons). Almost all the beacons are powered by coin cell batteries. A powerful micro-controller, Bluetooth module, memory space, motion and temperature sensors together embedded on a beacon.

Numerous business sectors including educational institutions, originalities, finance, retail, transit systems, travel, event organizing etc. have started using beacons based solutions to track and communicate with their existing and potential customers.

TABLE I. COMPARISON WITH OTHERS SYSTEM (WORLDWIDE).

	Type	System	Payment	Cost
Canada	Closed Access (Gantries at the entrance and exit points)	OCR and Laser Beam	Manual billing system	High
Poland	Closed Access (Gantries at the entrance and exit points)	GPS and GSM	Postpaid	High
Manila	Toll Booth	RFID/Tags	Postpaid	Medium
Italy	Toll Plaza	Pass receiver with gantries	Prepaid and Postpaid	Medium
Our System	Toll Booth/Plaza	BLE technology	Electronic payment/online payment	Bellow medium

Figure 8. Bluetooth low energy Beacon and its application scenario (photo: google).

Most of the retailer's shop nowadays uses beacons for exchanging product promotion with their customers. Beacons based payment system is also a hot research topic nowadays. More details of beacons are available in [8].

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