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RFID Based Toll Booth Management System using Internet of Things

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Abstract: Automation has played a vital role in the advancement of engineering and science. In recent times, traffic congestion on toll booths has been increasing day by day in countries like Pakistan. In such circumstances, there is a need to upgrade the Toll Booth Management System. A proper gate system is required to install on many organizations and institutions, which are being controlled manually by a security person. This process results in long queues of vehicles at gates, thus taking too much time and results in burning extra fuel of the vehicles. The system is still not secure. In this paper, the idea of making surveillance smart toll booth system that depends on Radio Frequency Identification (RFID) Innovation and online database has been presented. The automated gate system should be installed at every toll booth as a solution to this. After scanning the RFID, the system allows the vehicle to pass through the gate if data is present at the database. Otherwise, the automobile has to get approval from higher authorities. The developed system scans the RFID tag using RFID reader and compares it with database for authentication purposes and then automatically lifts the barrier up if that vehicle is permissible.

Keywords: Automation, RFID, traffic, toll booth, vehicle

1. Introduction

In the advancement of engineering and technology, automation is a regular term protecting the utility of mechanisms for the operation and regulation of processes without the involvement of humans. The biggest assistance of automation is that it conserves labor, time, energy, and improves accuracy and precision. The Internet of Things (IoT) is a system in which data can be transferred on the network and can be accessed whenever it is required. For the last few years, there has been an increase in the development of IoT technology. Therefore, the IoT is being used in the automation of transportation.

This automation helps people to avoid the problems of traffic on toll plaza. According to some experts, IoT has the potential to become one of the top breakthrough technologies of the next decade. A toll booth system is designed, which can be used on busy motorways and have the capability to pay toll tax without any problem [1]. Traveling is an essential thing in life. On toll plaza, much time is wasted in paying the toll tax at plaza while standing in long queues. The government also needs a lot of labor to manage the toll plaza and serve the customers. The purpose of this system is to save the time of customers and labor as well by automating the toll system [2].

This system is mainly based on Radio-Frequency Identification (RFID) and Android application for automation purposes. The motivation behind the development of an automatic toll booth system is to save the time of customers and decrease traffic jams on the road. It reduces the labor hired by the government to manage toll plaza. RFID has been utilized to control the toll booth system. The main aspects of this development are to facilitate both customers and the government. A Toll Booth Management System is designed, which helps in the automation of transportation [3]. The tolling system works through Radio Frequency Identification (RFID). In the RFID process, there is an RFID reader that emits radio waves. These radio waves are captured by the RFID tags placed on all vehicles. After scanning all the information on a vehicle, it is sent to an online server for security. After collecting information and deducting the

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balance from the user's account, the gate is opened, and a message is sent to the user. Also, all information is displayed on the LCD screen. The gate closes automatically after passing of vehicle for other users [4]. After the process of scanning, the gate remains closed for those who do not have sufficient balance or are not registered. A buzzer is installed, which rings for these users. The overview of the system is shown in Fig. 1.

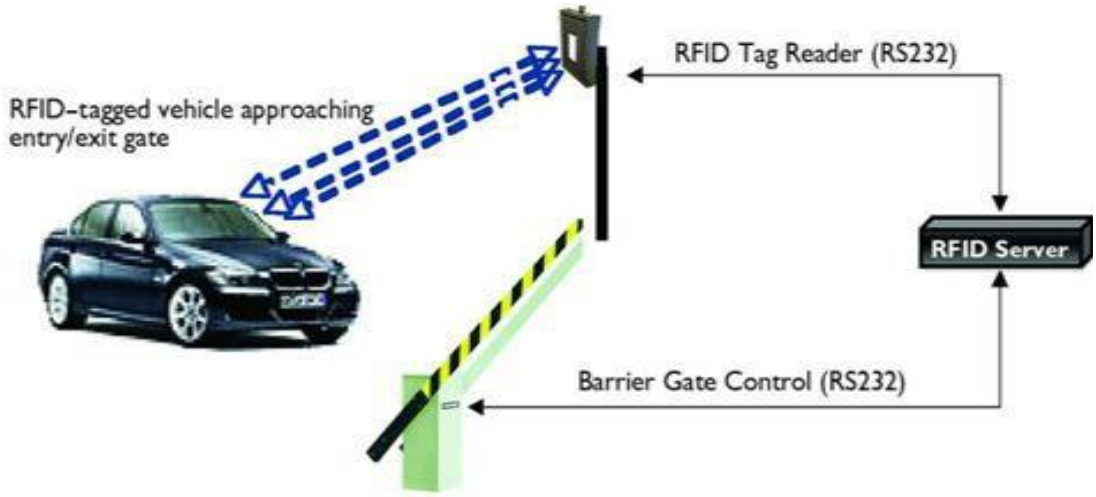

Fig. 1 - RFID barrier gate control

Fig. 2 depicts the system block diagram. In the system designed, each vehicle has an RF transmission tag that contains a unique ID for each vehicle. This unique ID is given to the vehicle's owner by the competent authority. This RFID tag continuously emits radio wave signals. These signals are captured by an RFID reader when a vehicle passes through the toll plaza. After the detection of these signals, these signals are sent to the microcontroller. The microcontroller sends this data to an online database, which is programmed in such a way that it contains information on registered vehicles and their owners. All the information on vehicles like the entrance time and the total remaining amount of money are saved in the database. After authorization of the vehicle, the barrier opens for the vehicle, and the vehicle passes through the toll plaza. If the user has less balance or not registered, the gate remains closed, and the buzzer rings. A message is also sent to the user by using the GSM module which contains the information of balance deducted and the remaining balance in users' accounts.

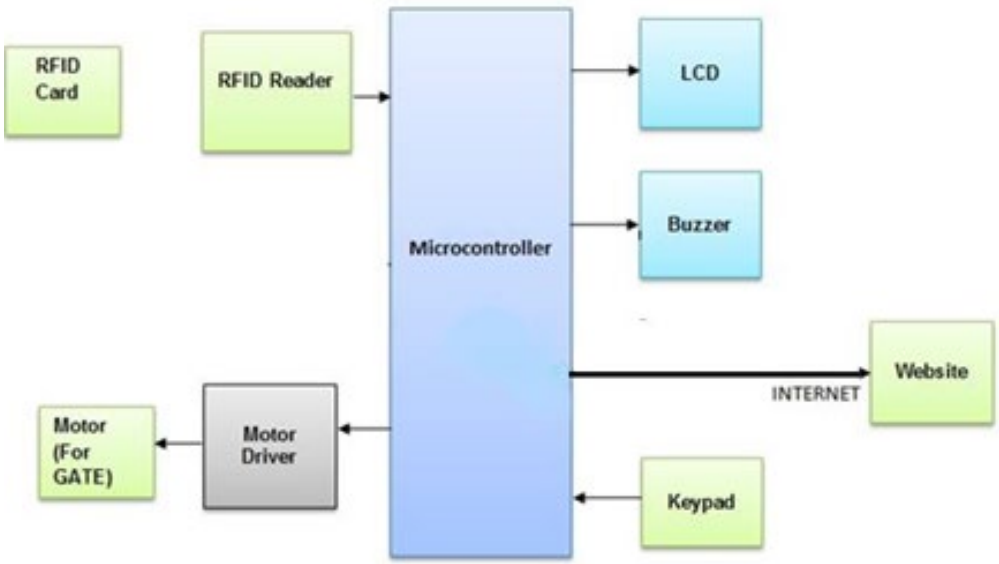

Fig. 2 - Block diagram representing the overall system

2. Literature Review

The total population of Pakistan is more than 212 million. They have a good transport structure. The developed road transport system is very important for any country. The total length of Pakistan National Highway and Motorway is 1820 km long, which is operational, and 2446 km are under construction. In the 90's decade or before that, the toll

plazas were not automatic. They were followed by manual methods. There were two people for opening and closing of the gate, and two were for receiving money and keeping data of vehicles [6].

In 1995, Express Ways developed the semi-automatic toll plaza. In this system, data was controlled by the network, and the gate was opened automatically by the press of a button. So, there is a necessity of two persons for each booth. Malaysia introduced an electronic toll collection system in 1995. After this, there had occurred a lot of development in this, and many new modern methods have been implemented. Recently they have introduced the system of Touch N Go and SmartTag system.

William Vickrey was the first person to introduce an electronic toll system for the Washington Metropolitan Area [7]. In the Philippines, an electronic toll collection system was introduced, which refers to the EPASS system. In this technology, electronic transponders that have the knowledge of vehicle details are kept in front of a vehicle's rearview mirror. Whenever a vehicle enters the toll booth, the transponder is read by the receiver. After verification of the vehicle and user account, the required amount is deducted automatically. After this, the gate opens for a vehicle to pass through it.

Trondheim introduced World's first full-speed electronic toll system. In the electronic toll system, vehicles can travel without any wait and reduce speed. If the lengths of the electronic lines are the same in the manual corridors, the electronic number saves the recording time of the vehicle. The people's Republic of China had introduced the ETC system in the mid of 2015. In Pakistan, the National Database and Registration Authority (NADRA) introduced an electronic toll collection (ETC) system using RFID. That was put into operation between 2004 and 2005.

In 2007, the US introduced a system that is followed by two lanes. On both sides of the road, antennas are installed for each lane. Both antennas are used for toll transactions. Side antenna and overhead antennas have their separate functions. The function of the overhead antenna is to capture the signal emitted from the vehicles. Side antenna performs its function when an overhead antenna does not collect the emitted signal due to any reason. In this case, the overhead antenna deactivated, and the side antenna is activated to capture the signal. If the side antenna also fails, then an error signal is issued. Tollbar used in Romania in 1877 is shown in Fig. 3.

Fig. 3 - Toll bar in Romania in 1877

The existing toll system in Korea is shown below in Fig. 4. When a vehicle enters into the tollbooth, a ticket is issued by the ticket issuing machine. After this, by the process of the vehicle identification system, vehicles are classified automatically. After this, when a vehicle driver reaches the toll gate, he pays the amount by hand in the form of a cash or debit card.

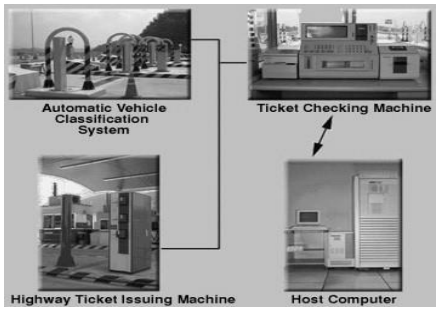

Fig. 4 - Toll system in Korea

The toll tax collection system which has been used currently in Pakistan needs manual involvement. The vehicle stops at the toll plaza. The vehicle owner or driver pays the toll at a toll booth, gets the receipt, and then vehicle moves ahead. This system is made our existing system completely automatic and primarily IoT based toll system as it can save time, space and money. In this system, each vehicle owner can have a tag with a distinctive tag number. This number is going to be related to the entire data such as owner name, vehicle number, vehicle type, current balance, balance

amount, current amount, RFID card number, and mobile number [9]. Currently, NHA Pakistan introduced the E-tag System on M-1, M-2, M-3, and M-4. Some existing toll booth systems are as follows.

2.1 E-TAG Toll Booth System

E-TAG is a system that has been used all over the world (see Fig. 5). Trans-urban originally developed this system in City Link tollway in the late 1990s. This system is based on radio-frequency identification (RFID) transponders. This system is operated by DSCR protocol. This system uses transponders that are unique and has been kept on the inside of the vehicle's windscreen [10].

Fig. 5 – E-TAG toll booth system

2.2 High Pass Toll Collection System

In Korea, Highway Corporation introduced the "Hi-Pass" electronic toll collection system in June 2002. In this system (see Fig. 6), on-board unit (OBU) is installed in the vehicle. The toll information is exchanged with this OBU system. After getting information, the gate opens [11]. There are three classes for the classification of targeted vehicles for the Hi-Pass program. First-class is for automobiles. The third class is for regular city buses, and the sixth class is for light automobiles. Till now, various vehicle classes have been introduced. The prepaid "Hi-Pass" cards are used for all classes. For regular city buses, the postpaid method is used.

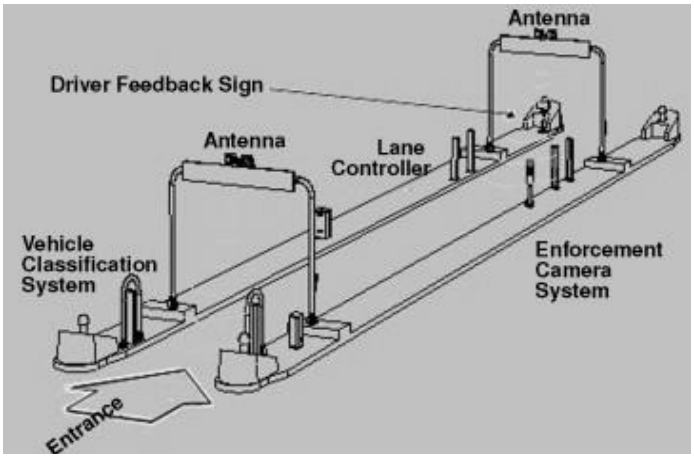

Fig. 6 - High pass toll booth system

2.3 Open Road Tolling

Open road tolling (ORT) is the process of collection of toll amount in which there is no existence of toll booths as depicted in Fig. 7. In this process, digital image processing has been used. The vehicle's number plate is scanned by image processing, and after verification from the database, the toll amount is deducted from the user account. Canada introduced the open-road tolling system in 2004.

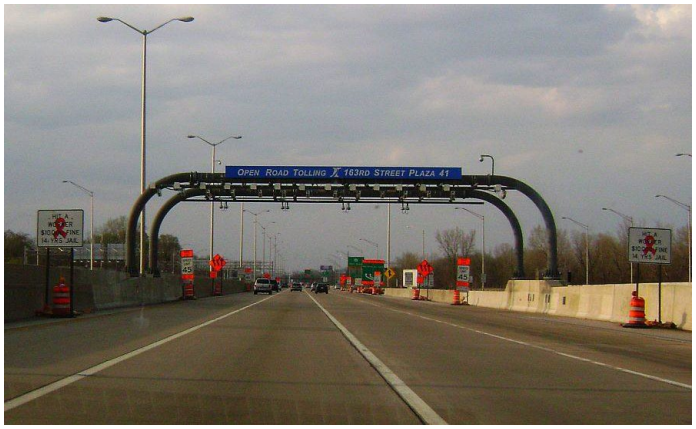

Fig. 7 - Open road toll booth system

3. Methodology

RFID based Toll Booth Management System operational methodology is expressed as follows. The main control of the system is done by NodeMCU that processes data from the RFID tag on the vehicle using an RFID scanner. Fig. 8 shows the workflow of the prototype model. Firstly, when the vehicle enters the toll booth, the vehicle is detected automatically by Radio Frequency Identification. If the RFID tag on the vehicle is registered with the system's database then the system checks if the cash is available. If cash is not available then it allows the user to recharge accounts. If cash is available then it deducts the balance from the account. The system uses these details of the amount deducted to update the database on the server and sends a message to the vehicle owner of the amount subtracted. The system opens the gate as it verifies the detail of the vehicle. The system alerts the user through an Android application that the amount is charged, and the vehicle can pass through the toll booth. The Android application also gives the user information about the entry and exit of the vehicle from the toll booth. When a vehicle arrives at the toll booth, the system scans the RFID tag. If the RFID tag is not registered then the system generates the alert “cautious activity” and the buzzer turns on. C/C++ is used for RFID scanning, connecting to a server, and motor working. Android Studio/Ionic JFrame is used for developing an Android application for users.

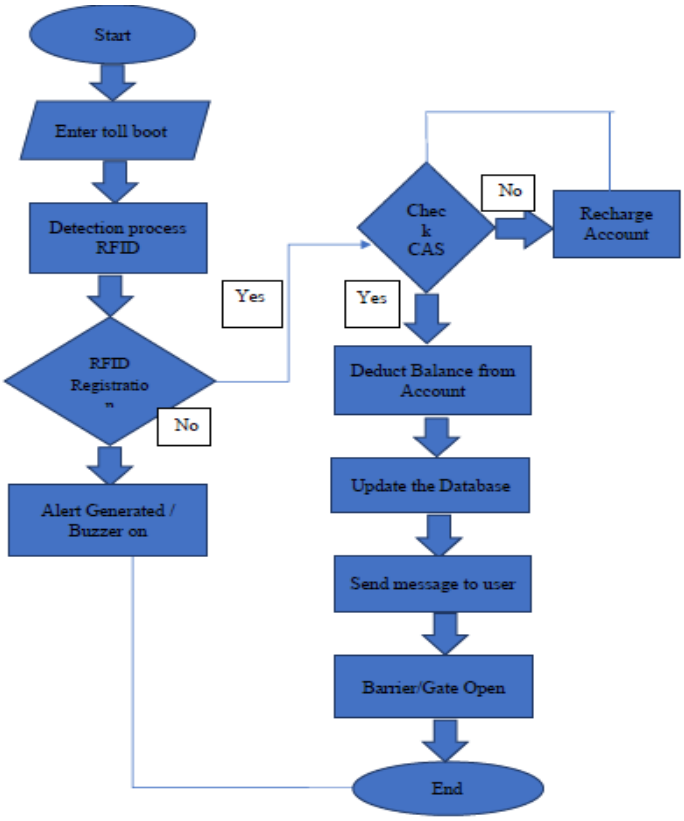

Fig. 8 - Working flow chart

4. Hardware Implementation

4.1 Development Stages

The employment of the system is divided into four development stages and one integration stage. The brief explanation for each stage is as under.

4.1.1 Stage 1

In the initial stage, as shown in Fig. 9, the assessment of data was done through hardware. The user puts the RFID tag in the short-range. Once the RFID tag comes in the range as it was placed on the vehicle, it was detected by the reader module, which emits radio frequency signals. After the identification of the RFID tag, the RFID tag can read and write information to the reader module. After the transmission of information to the RFID reader, this can now be sent to NodeMCU [14]. The Wi-Fi module takes this related data and transmits it to the online database server PHP. The microcontroller acts as the main master of the system. The online application of the system has been implemented through the internet of things IoT.

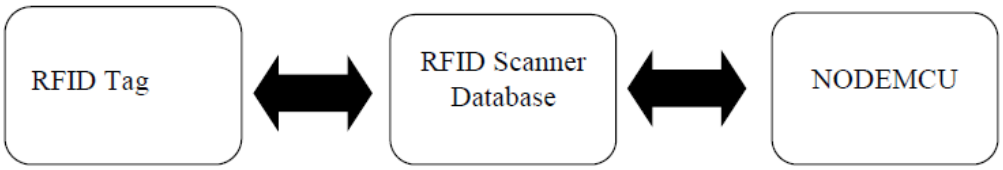

Fig. 9 - Stage 1

4.1.2 Stage 2

In the next stage as described in Fig. 10, once the user is recognized, progress shows to move on to the next point. A subsequent amount is deducted equivalently from the reference amount for expressing the successful completion of toll booth operation. Once the operation completes, the microcontroller (NodeMCU) operates the toll gateway by driving the motor. As the vehicle passes, the RFID signals the motor to close the toll gate [15]. The transaction amount to pay toll tax is shown on the display unit.

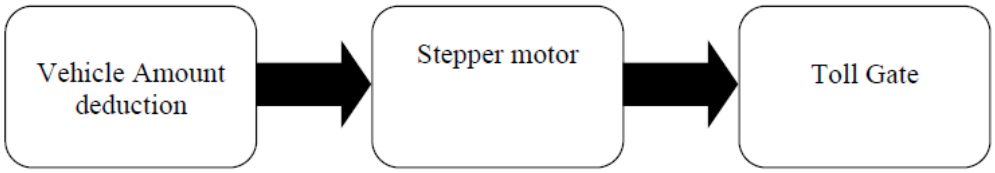

Fig. 10 - Stage 2

4.1.3 Stage 3

In the third stage as depicted in Fig. 11, PHP was used as a backend language for Web view and Ionic Framework for Android application. A WebView was created using [16]. HTML/CSS was aimed to be at the frontend and then the creation of a database "MySQL". With the help of PHP, a connection builds up between Web and Database. The architectural overview is shown in Fig. 12.

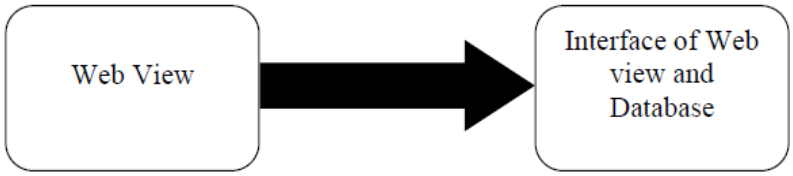

Fig. 11 - Stage 3

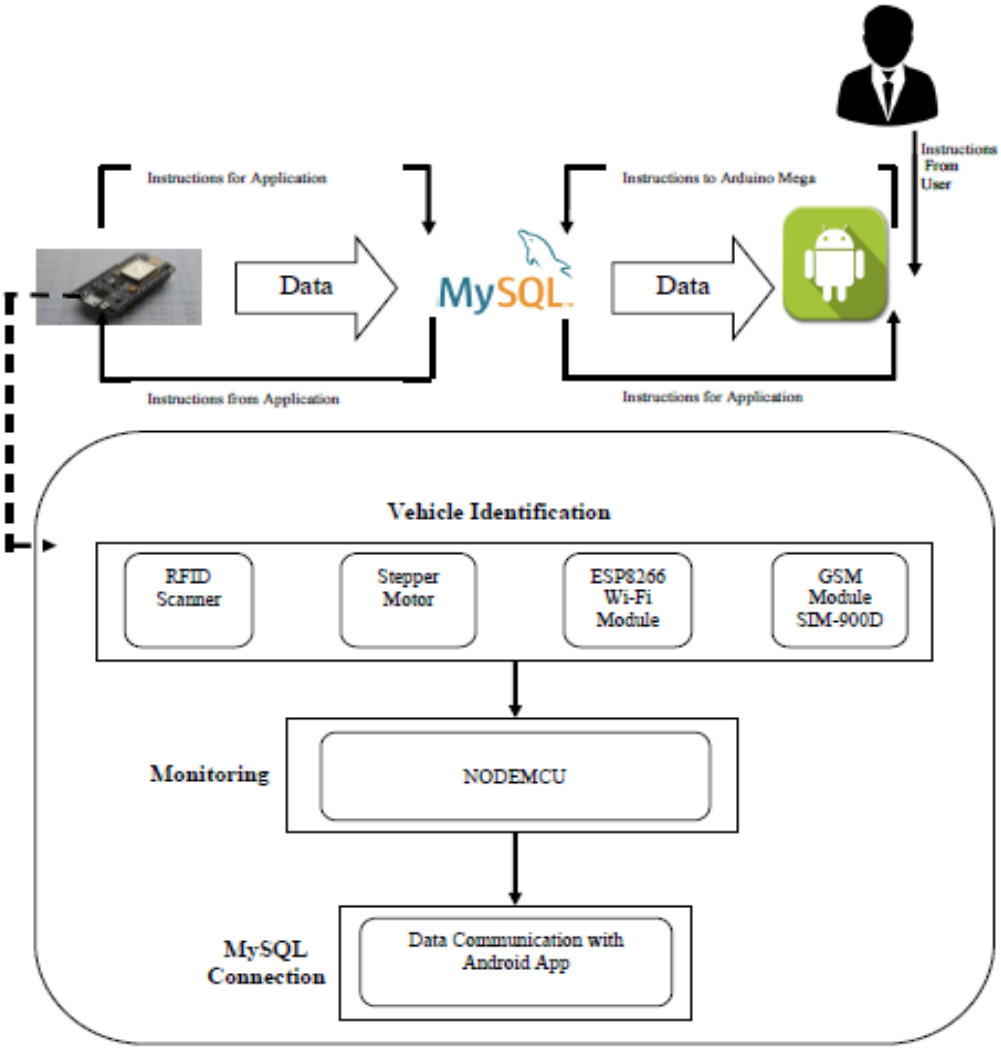

Fig. 12 - Architecture overview

4.1.4 Stage 4

In the fourth stage, after the testing deployment of WebView was done on a free hosting server, i.e. 000webhost.com [17], an Android App was made to interface with the web (see Fig. 13).

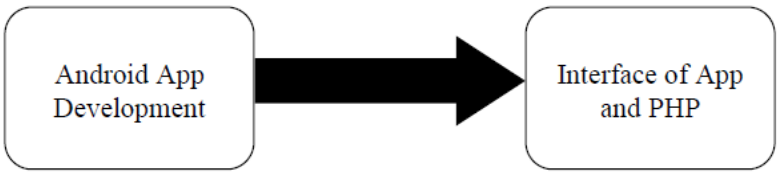

Fig. 13 - Stage 4

4.1.5 System Integration

In the final stage, after all the errors and bugs were exposed and cleared, the complete implicit division of the system was ready. The program is linked by the creation of a Graphical User Interface (GUI) (see Fig. 14).

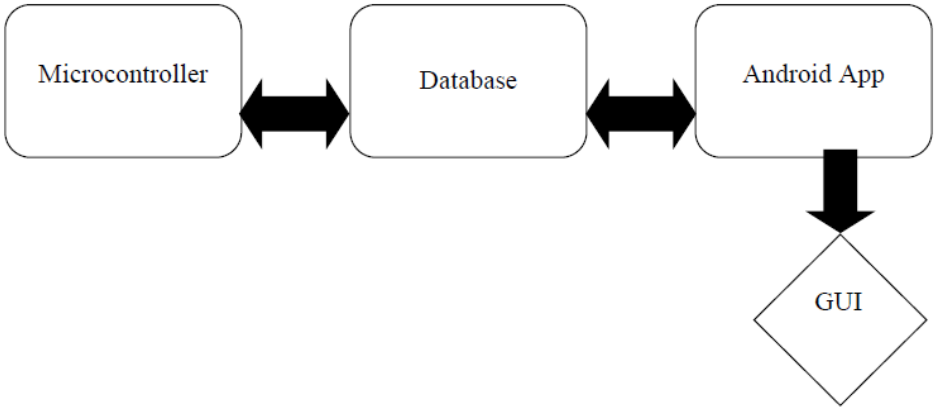

Fig. 14 - System integration

5. Hardware and Software Testing

5.1 Hardware Testing

In the initial test, the scanning of RFID was done from RFID tags. This further involves detecting an RFID number ID of the vehicle. The detected vehicle is searched by using RFID numbers in an online database on microcontroller NodeMCU using C++. The amount to be paid is deducted at the toll booth of registered vehicles. The interfacing of NodeMCU with data server and creating is made. A web page is constructed for database management to obtain desired results. Figs. 15 and 16 are shown for the gate opening and closing.

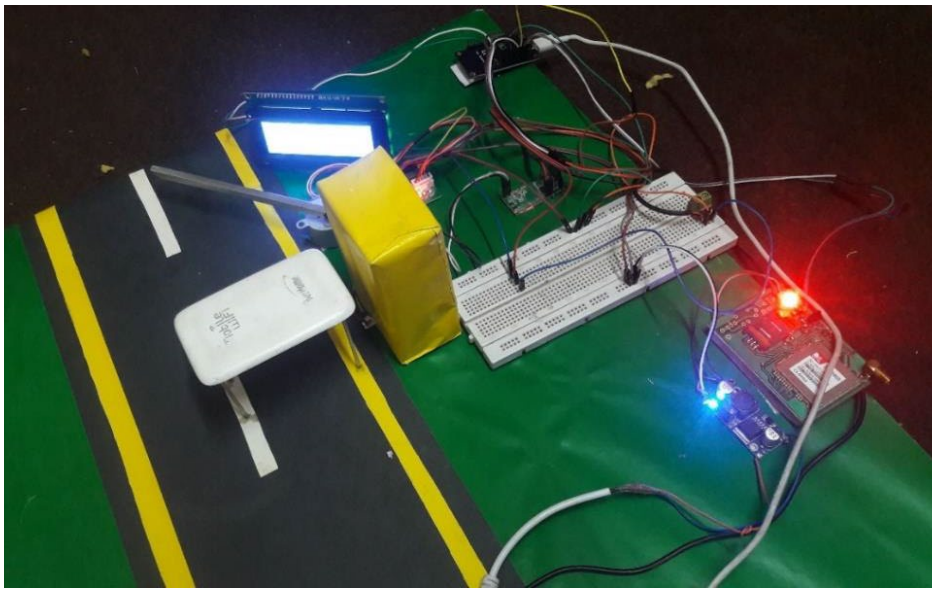

Fig. 15 - Opening of the gate

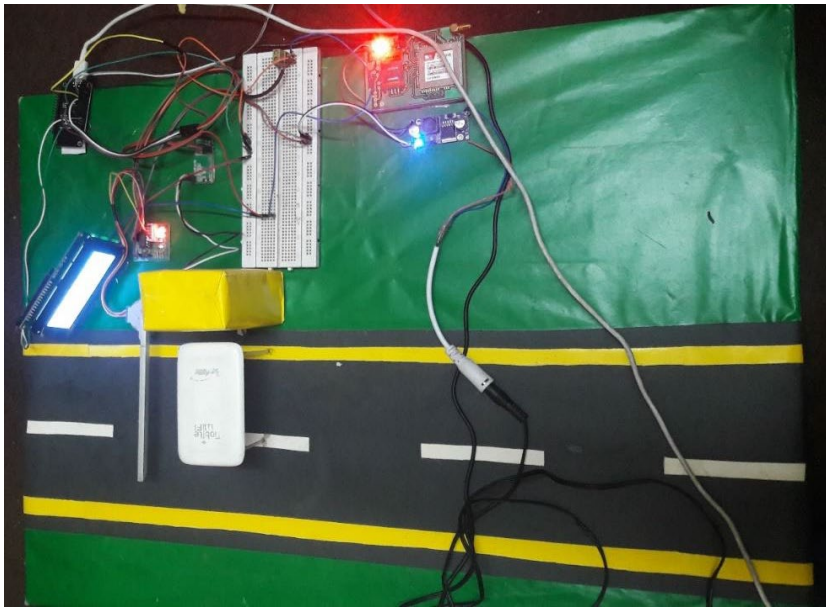

Fig. 16 - Gate closing for next vehicle

5.2 Software Testing

Software testing was done in a set of stages, which includes testing of:

- Scanning of RFID from RFID tags
- Detection of RFID number
- Searching the detected vehicle by using an RFID number in the database
- Deduct the amount to be paid at the toll booth of the registered vehicles
- Creating an algorithm for sending message
- Hosting of the data server
- Creating a web page for database management
- Android App development for user interface
- Record maintenance on the MySQL server

5.3 Results

The following results have been recorded from the webserver.

5.3.1 Web Login Screen

Firstly, the online database for authorities to keep data of registered vehicles was created. It was done at an online database on 000webhost.com. The first screen after entering into a database is shown in Fig. 17. The name of this system is the Toll Booth Management System. In this system, it asks for entering username and login password. After entering the username and password, one has to submit these details to move on to the next screen.

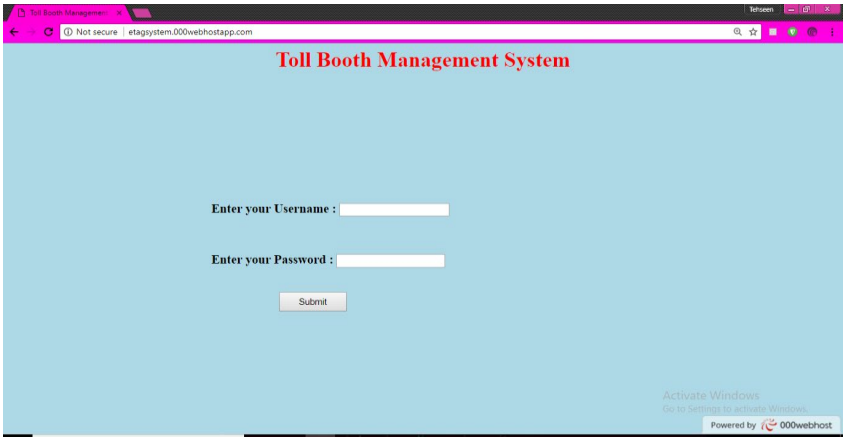

Fig. 17 - Web login screen of Toll Booth Management System

5.3.2 GUI of Web

After submitting a username or password, the system checks whether the provided details are correct or not. If the required details are not correct, the system asks for entering the username and password again. If the required details are correct, the system takes you to the next screen. The screen is shown in Fig. 18. On this screen, there appear four tabs. In the View List, there is a list of registered vehicles. In New User, one can add new users. With the help of Add Amount, one can update the number of registered vehicles. By using Delete User, one can delete the registered vehicle from the database.

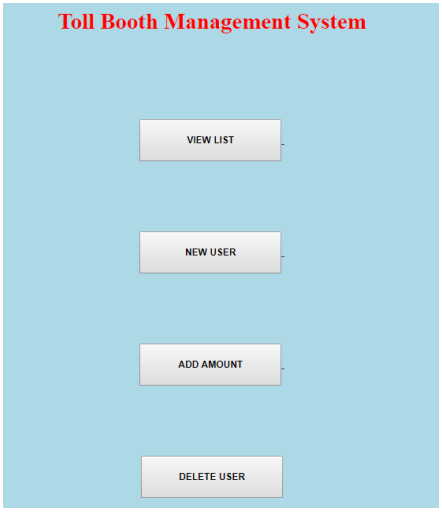

Fig. 18 - GUI of the web of toll booth management system

5.3.3 Vehicle Record

After clicking on the VIEW LIST, a new screen appears. This screen shows the record of all registered vehicles as shown in Fig. 19. This table shows the name of the vehicle's owner, CNIC number, vehicle type, vehicle's registration number, RFID number, phone number, and amount of balance. So, one can keep the data of registered vehicles in this table.

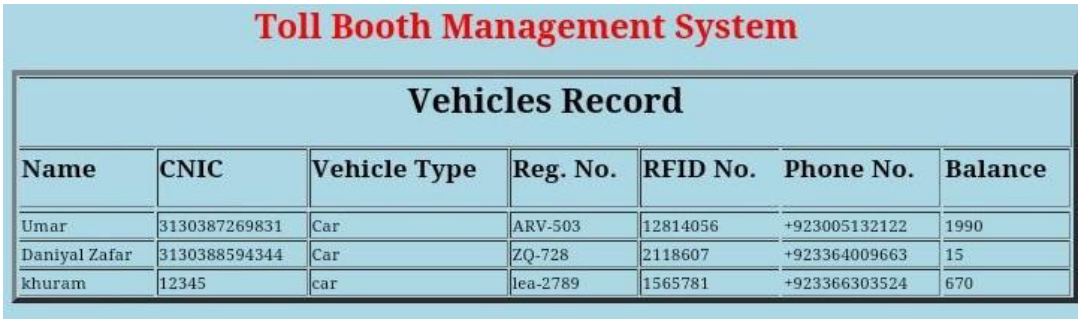

Fig 19 - Vehicle record list of Toll Booth Management System

5.3.4 Vehicle Registration

After clicking on the NEW USER, there appears a new screen, which is a vehicle registration screen. This screen asks for filling in many fields as shown in Fig. 20. One has to fill these fields for registration of the vehicle. This screen asks for entering the name of the vehicle's owner. After this, it asks for the CNIC number. Then it asks for a vehicle's type. One has to enter a vehicle's registration number, then. After this, one has to enter the RFID number which has been assigned to this user. Then it asks for a user's mobile number for sending a message about his account details. Then one enters the amount of balance which a user wants to keep in his database. After entering all the required details, one has to save these details. After saving these details, the user gets registered in an online database, and this user has the authority to pass through a toll booth.

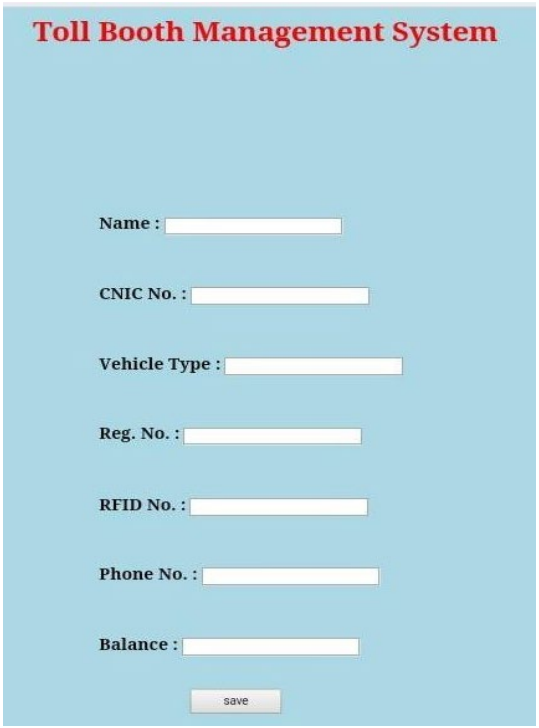

Fig. 20 - Vehicle registration screen of Toll Booth Management System

5.3.5 Toll Booth on Line Screen

After interfacing the hardware part with the software part, the Toll Booth Management System is ready to run. After giving a supply of 5V, the system runs, and LCD turns on. A message appears on the LCD screen, which welcomes the vehicles entering into a toll booth as shown in Fig. 21.

Fig. 21 - Welcome screen of Toll Booth Management System

6. Conclusion

The presented prototype of an "RFID based Toll Booth Management System using the internet of things (IoT)" allows us to make vehicle identification, after deducting a fee from the user's account, and the user is free to go. The GUI of the toll booth system allows the admin to collect toll tax. The system gives us the following benefits such as: waiting time for the vehicle is reduced, ensure precise collection of fees, the cashless transaction takes place and cost-effective system. It provides a reliable gateway with good management and monitoring. The model of the system acquires data through an RFID scanner that scans the RFID tags, and this data is sent to an online server. It checks for vehicle registration and then deducts the toll tax amount. Its productivity is improved through the development of an Android App for user edge, and MySQL online server helps to maintain vehicle records. This system successfully fulfills the requirement of an automated toll fee collection system. The model of the system can be more efficient and dependable for better results if subsequent work can be done in the future like a navigation system for an App to be merged with Google Maps, multiple recharge options like payment through easy paisa, and so on. SMS alert on the Android App. Employment of image processing for integrated data recording.

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