Developing a Solution for Intelligent Urban Transportation Management Using the Internet of Things

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Abstract

The increasing use of technologies based on Internet of Things in cars and other transportation vehicles, as well as innovations in tracking systems and spatial information systems, have created the opportunity to collect tolls on urban roads in a more intelligent, more efficient, and a wider way. Considering the cultural and infrastructure variables in different cities, different approaches have been designed for this purpose, but so far, no work has been done in this area in Tehran. Therefore, in this research, a system of hardware and software based on the Internet of things was developed based on global positioning system (GPS)/ global system for mobile communication (GSM) for automated urban tolls in Tehran, which manages the location of a user's car and manages toll payments at any given moment. In addition, in this system, considering the cultural issues in the country, the infrastructure in the metropolis of Tehran, and important issues of the city, the trespass submission system is designed in accordance with the existing surveillance cameras and an infrared-based structure was used to reduce the burden of image processing in order to improve efficiency. The data obtained from this system will have more potential than only the urban toll management.

Keywords: Intelligent Transportation Systems; Internet of Things; Vehicle Tracking System; Electronic Toll collection; global positioning system (GPS), Infrared

1. Introduction

The development of high-speed Internet networks, along with the dramatic expansion of the World Wide Web has led to the emergence of a large number of Internet-friendly devices [1-3]. With regard to the fact that, the accelerated expansion of cities brings more and more challenges regarding traffic, the use of intelligent transportation technologies such as intelligent transportation system (ITS) will make the traffic management in transportation working more easily. Aforementioned technologies would fundamentally change city management and citizens' use of transportation networks [1, 3-4].

Due to the importance of monitoring the traffic by means of checking speed limit, pollution check, and emergency response in the case of road accident, internet of things (IoT) technology emerged with a variety of ways in traffic management. For example, the ITS is projected to significantly improve road transportation and safety [4]. Using the Internet of Things in order to achieve transportation strategic goals would result in an optimal use of transport resources. In fact, the Internet of Things has specific functions in transportation, such as non-stop electronic tolls payments, intelligent transportation systems, scheduling and transferring emergency commands via mobile phones and vehicle Anti-theft systems [5]. With regard to the heavy daily traffic on urban highways, the urgency to reduce the urban pollution and encourage citizens to use public transport by governments, and huge maintenance and construction costs of structures, the management of routes is becoming more complex. Therefore, there is a need for newer and more dynamic models [6]. Hence, increasing use of modern technologies in cars and other vehicles, as well as innovations in the tracking systems and spatial information systems, has created a more intelligent, efficient and wider opportunity in terms of collecting tolls in urban roads. This approach would also result in purposeful revenue from traffic [7].

The intelligent urban toll is one of the newest and most significant subdivisions of telecommunication solutions and global positioning. There are various challenges in traditional ways of receiving tolls such as a huge amount of wasted time in collecting tolls in person and creation of long lines of traffic. Moreover, it is nearly impossible to receive tolls at busy times due to heavy traffic loads. One should also consider the difficulty of physical money transfer, the possible trespassing of certain cars, the impossibility of imposing tax exemptions on specific vehicles, the abuse of personnel in receiving the payments, as well as the unattainability of applying tolling policies based on conceptual designs such as time-based costs and access tariffs, cost of area or distance, in addition to the high costs of road construction and the urgency for traffic control and air pollution. With the recent developments of technology and mentioned difficulties, governments were led to use technology to increase accuracy and satisfaction [7].

Intelligent toll payment systems for urban roads are highly dependent on the technical infrastructure, urban features and cultural issues of each society. As a result, each system is designed and developed according to the culture, technical infrastructure, and the technology of each country. This issue is also important in Tehran metropolis since many specific issues exist in this area, which requires a dedicated strategy like other metropolitan cities. Therefore, this research tries to develop a strategy for managing urban fleets based on location-based networks. The proposed approach is focused on urban toll payment systems which are developed on Iran's culture, local parameters, and existing infrastructure in the country. Moreover, it contains the ability to integrate data through service-oriented systems and provide data and analytical information to various elements.

According to Numbeo's website, Tehran is ranked fifth in the wasted time duration in traffic jams, and Iran holds the worst position. Accordingly, Tehran has ranked 218 out of 222 cities and losses the most time in traffic. This problem is caused by the negligence of significant issues such as dynamic pricing based on environmental factors such as air pollution, existing country's infrastructure, and people's tendency in non-obedience.

This suggests that in the event of non-tackling the traffic issue and planning and pursuing technology-based solutions, the government will face numerous problems in the near future in terms of transportation inside the metropolis. Moreover, the huge volume of car production inside the country would make the matters worse. Hence, the urban intelligent toll payment is a necessary issue in order to direct citizens to use more public transportation while collecting urban data for the infrastructure development and coming up with the monetization methods for municipalities which will help them to develop transport infrastructure [7]. Therefore, in order to provide a solution for intelligent management of the urban fleet based on the Internet of Things, this study attempts to implement a system for the automatic urban toll payment which will be in accordance with the hardware and software infrastructure of Tehran. In general, the purpose of this research is to provide a technical architecture for intelligent urban fleet management. Studies on intelligent payment systems for tolls on urban highways in different countries have shown that the system should be chosen based on the existing culture and infrastructure of each country and it should be in line with its development process towards intelligent city development. Therefore, on the basis of these topics, another aim of this research is to develop a two-fold approach based on the Internet of Things for managing toll payments in Tehran's streets.

Despite the shortcomings of the radio frequency identification (RFID), it was used in this study to decrease image processing load and preventing fraud by keeping the system active. In this way if the installed system on the car is inactive the surveillance cameras will capture photos, and the image processing load will be divided between system and cameras. In this way, if RFID has some percentage of fail, the whole system will work properly because the captured photos will check again in the system to examine the performance of module on the car. With regard to these purposes, first, the literature is explained, and subsequently, the methodology and research tools are evaluated from the software and hardware perspectives. Then, the proposed strategy is designed and implemented, and finally, the conclusions and recommendations of the study are discussed.

2. Literature Review

The Internet of Things (IoT) is a complex network of objects and individuals that connect seamlessly through the Internet. Anything with the potential for connection can be joined to this network in order to exchange data through wireless sensors and radio frequencies [8-10]. The Internet of Things is expanding in a number of areas such as health [11-12], business [12], environmental monitoring, homes [13], and transportation [14]. The IoT assimilates a huge number of objects which continuously produce information on the world over standard Web browsers. Any virtual object such as integrated small chip, sensor, or embedded system include the IoT. These virtual objects can provide the desired data or information toward a common goal [1].

Furthermore, the Internet of Things offers specific functions in the field of transportation such as automatic toll payment collection, intelligent transportation systems, scheduling and emergency commands via cellphones, and vehicle anti-theft systems [4]. The intelligent transportation system (ITS) enables the coordinated and integrated use of tools, facilities, and expertise such as traffic engineering, software, hardware, and telecommunications technologies to improve the performance of transportation systems [3, 14-16]. One solution pioneered by ITS is intelligent urban tolls [17], whereby drivers pay toll fees on highways and other roads without having to stop the car, with the cost being automatically deducted from the driver's bank account. This system is also used in urban areas to collect fees at traffic planning sites [18].

Considering the continuously entering of new vehicles on the road the traffic control is the most important problem that should be solve. The delay in traffic information delivery, accidents, vehicles break down and are the major reasons of traffic congestion [19]. The electronic payment system contains specific software technologies including an automatic detection system for vehicles, which detects vehicles passing through with the help of hardware equipment [20-21]; an automated vehicle categorization system that identifies and categorizes the vehicle type; a transaction processing system that records the cross-axis transaction for the user, after identifying the vehicle [7]; and a system for identifying violations and deducting unpaid tolls [22]. Alongside this software technology, electronic toll payment systems make use of various hardware technologies for the paying of tolls on the highway including RFID Units, which respond to radio signals via a RFID chip installed in a unit or label on the windshield near the rear-view mirror of the vehicle [23]; video toll systems that use aerial cameras to identify vehicles at the toll [24]; a dedicated short-circuit communication system, including a transmitter and receiver, which deducts the desired amount from the inventory, based on credit cards [25]; and the visual protection surfaces (VPS) technique that stores vehicles' coordinates and sends transaction information to toll agents through the Global Mobile Communications System [7].

Intelligent urban toll systems are dependent on the technical infrastructure, urban features, and cultural issues of each community, and the success of such projects usually requires an understanding of the specific environment of each system that is implemented. As a result, these systems are not typically used individually, but rather in combination with several other systems in place on highways. One of the electronic toll payment systems in use in Canada is known as the Canadian toll road 407. Here, a system of cameras and transmitters is used to automatically collect toll payments from vehicles, and so does not employ traditional booths for officers to collect toll payments [18].

Radio antennas calculate the rate of charges once they detect a vehicle with the transmitter, enter in or exit the highway. For vehicles without a transmitter, an automatic license plate number identification system is used. Subsequently, the invoices are sent directly to the registered address of the vehicle owners each month [25]. Similarly, Telepass is the commercial brand of electronic toll payment system, which is used on highways in Italy. This system uses the VPS method and includes an on board unit installed on the top of the front screen. In this system, the toll charges vary and depend on the type of vehicles and the cost of maintaining and repairing the highway [26]. The electronic toll payment system, which is used in Singapore with the aim of road traffic management by road pricing is a combination of two desiccated short-range communication technologies and video toll payment. In this approach, a receiver is placed on top of each gate and the cameras are connected to the gate, which take photos of the vehicles' plate number. When a car passes through the gate, the cost of using the road is deducted from the cash card. The sensors installed on the gates communicate through a dedicated short-circuit communication system and the deducted amount is displayed to the driver on the liquid-crystal display screen [27].

A hybrid system of video control and EZ label was designed in the US, which allows drivers to pay tolls without the need to stop at stations. Drivers enroll in the EZ Website, either through telephone or in-person. Afterward, they receive a small, white EZ label that is to be stuck on to the front windshield on the back of the car's back mirror. Thus, when they cross the toll area, drivers of special lines who are equipped with a receiver can pass through these lines and the amount will be deducted from their accounts; correspondingly, the trespassing drivers are photographed and fined [28]. Table 1 indicates the combined solutions for smart payments in different countries.

Electronic toll payment solutions on urban highways are one of the fundamental and most influential infrastructures in the smart city, and each society should move towards it. Since, socio-economic, educational and cultural factors are effective on traffic related facilities [29], analyzing different systems in various countries indicated that each country, based on its infrastructure, urbanization features, cultural issues and users' approach in the use of different systems and direct or indirect access of drivers to the Internet, uses different combined models to achieve maximum performance. Hence, a well-used strategy in one country may not be accepted in another society.

Considering the culture of the Iranian people and their interest in law aversion and non-payment of taxes to the government and based on the available infrastructure in the country and access to the Internet, this issue is also of interest in the Tehran metropolis. Specific issues such as air pollution, traffic, travel times, weekdays, and more are considered in this metropolitan area which requires a dedicated solution to expand, like other metropolises around the globe. Therefore, the aim of this research is to investigate the toll payment systems on urban highways, its existing challenges and solutions, and to provide a suitable solution according to Tehran's infrastructure and demands. As a result, a dynamic pricing model is considered that is intended to meet the needs of the Iranian market.

3. Research approach

This research has a constructive approach. The purpose of using the constructive approach is to solve the practical problems while creating a share of academic theories. Constructive solutions can be processes, practices, tools, or organizational charts. In this approach, data is collected from the real environment, and after the model construction it is tested in the real environment [30].

In this research, a system of hardware and software based on the Internet of things is developed on the basis of global positioning system (GPS) and global system for mobile communication (GSM). In the hardware section, several different tools have been used including, Arduino's microcontroller, which is responsible for receiving information from GPS modules and sending it to the server via the GSM module as well as sending infrared codes, Arduino can be situated on the computer system as one of the components while it has a very strong hardware for electronic projects. Arduino does not require any operating system or software to run, a code is enough to use this device. In addition, GPS and GSM modules have been used to receive vehicle location information and transfer the data to the server via the Arduino platform. Moreover, the infrared system is used to reduce the image processing load and improve the efficiency of the system for detecting violations based on the existing surveillance cameras. Infrared receivers are a kind of diode. Their resistance changes with the amount of the infrared radiation meaning that when they receive infrared rays, their resistance increases and they produce a lower output voltage.

Infrared systems are not sensitive to time changes due to the inherent diversity of the receiver. This simplifies the design and increases the operational credibility [31]. In this project, the TCRT5000 module is used to send and receive infrared waves which is able to obtain user's vehicle location data at any moment and send it to the server. The reason for using this module is its affordable price and its availability in the domestic market compared to other similar modules. In addition, the proposed system has several different software tools including the C ++ programming language to develop codes for the Arduino-based device installed on the user's vehicle, the PHP programming language to develop receiving and sending data on web services, and the user's information processing unit within the Laravel framework and the MySQL database to store information. The primary reason for using MySQL in this project is its excellent alignment with PHP and its open source, which is considered as an important element in government systems. The information in the relational database systems is not object-oriented. To facilitate the usage of database information in object-oriented applications, object-relational mapping is used so that these data are converted into suitable data for use in object-oriented languages. Using Eloquent, SQL commands are sent to this tool with PHP, and it interprets commands based on the type of database.

In addition, other complementary web services are used to obtain more information and calculate the price in the proposed system including Google Map API, Google's routing service, air pollution service provided by the Tehran Municipal Air Pollution Control Agency which shows the weather real-time information is in Tehran's 22 areas, and the weather service provided by Dark Sky Company.

3.1. Solution Design

Hardware solution

In this research, two hardware systems have been used including, the user hardware that is installed on the vehicle and the server hardware that is installed at the highway entrance. One of the main requirements for the desired system in Tehran is the receipt of real-time information from vehicles. By receiving the real-time information, it is possible to online estimate the traffic volume, the time and kilometers usage, the weather conditions and the amount of pollution in that area. Therefore, it would be possible to implement dynamic pricing. To meet this need, the GPS module is used to get the momentary positioning of the vehicles, which also allows the vehicle speed to be recorded.

The next issue is to send the information received via GPS, for this purpose it is possible to use a radio system which is unique to the project. However, due to the proper infrastructure of the mobile Internet in Tehran, GSM platform has been used which provides high developmental capabilities and an online affiliate with a very good approximation for the system. In this approach, the microcontroller receives the user's location every 30 seconds through the GPS module and sends it to the server through the GSM module.

Since any vehicle can easily trespass the electronic payment system by deactivating the module, the GPS/GSM module cannot work alone; therefore, there should be another strategy to combine the system with other elements which operate independently so that the user would not be able to deactivate the system. For this purpose, a camera is used to record violations. However, the overload image processing is still a big problem that alongside the overload of the comparison of records with those recorded in the server through the system installed on the car raises major problems and high response time for the system.

Therefore, due to cultural and infrastructure problems, the complementary infrared module strategy is used to solve this problem in such a way that several rows of infrared receivers are placed under a glass layer on the floor of the highway before the camera is positioned. Also, an infrared transmitter module in the user's car will be connected in series to the GPS/GSM module via the Arduino microcontroller as the power outage of each module removes the other ones from the cycle and the infrared module continuously sends its own code. The schematic structure of the proposed system is depicted in terms of hardware In Figure 1.

As shown in Figure 1, the vehicle's reporting system will be placed under the car hood and will connect to the main car's power. It will send the data to the central server via the GPS module. the infrared sensor will also be placed underneath the car, and the receiver sensors will be placed underneath a glass layer on the floor of the highway, and three surveillance cameras will monitor three traffic lines in use so that in case no information is received through the infrared receiver sensors it will take pictures of the car passing through that particular route. The schematic of the implemented system at the entrance of the highway is shown in Figure. 2.

Software Solutions

The user's location is sent to the server via the GPS/GSM module installed on the vehicle and an information web service. After receiving the information, the software section of the system is activated. The user's location is sent to the server via the GPS/GSM module installed on the vehicle and an information web service. After receiving the information, the software section of the system is activated. First, the information sent by the system placed on the user's car is examined in order to define whether or not the secured security code is correct. If the code is correct, at the next step it will be examined whether or not the user has an open account for attending in a range of registered highways in the system.

If the user does not have an open account, it will be checked whether or not he is within the limits of a defined highway in the system.in case it is within the boundaries of a highway, a new invoice on an open account will be opened for the user. On the other hand, if the user has an open account in the system, the system will check whether the location sent from the user is related to the same highway. If the user is still using the same highway, location status won't be sent because the related invoice has already been created for the user and it will be closed when the user exits the highway. In the following step, toll charge will be determined by the dynamic pricing models described below, the invoice is issued, and recorded in the system. The user will have 24 hours period to recharge his account for the deduction of this amount, otherwise, the user will be fined. Consequently, the user's departure point will be checked in order to verify if it's another highway within the service range. In case the user is within the range of another highway that is defined in the system, a new invoice will be created for the user otherwise the process will end. The operation mechanism of the software system is shown in Figure 3.

3.2. Implementation of the solution

- *Implementing the hardware section*

For the implementation of the hardware, we start with the SIM808 module, which is responsible for receiving user's spatial information, as well as connecting to the Internet network via GPS/GSM. This module, which is placed on the restriction of hazardous substances launcher board, requires a general packet radio services (GPRS)-enabled mobile phone SIM card (subscriber identification module). It also has two ground inputs and a 5-volt power input that provides information to the microcontroller via two input and output terminals. However, the SIM808 board does not include an internal antenna for connecting to the GSM network, as well as the GPS network. As a result, it's necessary to connect the two antennas. In the next step, the SIM808 module should be connected to the he Arduino Uno which is an open-source microcontroller board based on the Microchip ATmega328P microcontroller.

Afterwards, the GPS/GSM module must be connected to the microcontroller, since the infrared modules and display will be added to the system in the next steps and the board will be used to distribute the power between all modules the two inputs and outputs of the GPS/GSM module will be connected to two Arduino digital inputs and outputs. Due to the inability to implement a large receiver system under the glass sub-layer underneath the highway, both transmitters and receivers are connected to a microcontroller so that their information capacity can be tested in the software section. The TCRT5000 Infrared Module is used to send and receive information. Both infrared modules are ready to be connected to the breadboard and Arduino. The TS1620A-17 LED module is used to display information and view how the commands are executed. This hardware system can be connected to a computer via Arduino and a Universal Serial Bus (USB) cable for programming as well as connecting to an energy source for its power supply. In addition, there is a possibility to connect this system to a 5-volt adapter via Arduino. Figure 4 shows the final output of the hardware system.

- *Implementation of the software section*

The software developed for the proposed service comprises of the component installed on the user's device and that implemented on the server.

- *Implementation of the user software*

The software required by the user is placed on the Arduino microcontroller and provides the ability to send information in 30 s intervals. To use Arduino, its connected modules must be activated and the location must be obtained by the GPS module. This allows the latitude, longitude and velocity data received from the GPS module to be placed into a string variable. Afterwards, a GET request including the location, speed, and user's ID is sent to the server. In addition to the Loop function for transferring location information, another Loop function is used in the microcontroller to send infrared data.

- *The software Implementation for the Server*

The server-side software comprises of several components, one of which is the web service that obtains the location information from the device placed in the user's car. This GET request type web service is called via the user's device and provides the server with a string value that includes the longitude, latitude, vehicle speed, and unique code of the user's device through the uniform resource locator (URL) parameters. The server-side software also contains the main module, which is fully implemented in accordance with the solution. First, it checks whether the user's specific code is correct. If that is the case, the submitted location will be checked in order to verify whether the user already has an open account related to previous locations. If an active invoice has been created for the user and the user is still on the same highway, the system will discard the current request. On the other hand, if the user has exited the highway for which the invoice has been previously created, the cost related to that part of the journey will be calculated and the invoice will be closed. Finally, the server-side software checks whether the user has entered a new highway after exiting the previous one, as this would generate a new invoice. The new highway is already in the toll plan and its polygons are defined in the system.

3.3. Cost (Price) Calculation

When considering various dynamic pricing methods, different options should be considered in Tehran. For example, while the charge should be based on the distance traveled on the highway [26], different rates could be introduced for peak periods, holidays, etc. This requires hourly pricing regime, whereby 24 different prices per highway would be related to each day of the week [32]. For example, if the user has traveled 2 km on the highway at 2 pm on Thursday, the price can vary compared to another car that traveled the same distance at 4 pm on the same or another day.

The type of vehicle must also be completely defined in the system, as this would have implications for the hourly pricing. For example, a passenger car would incur different cost compared to a taxi or a truck [32]. Next, the traffic conditions of the highway will be analyzed [26]. Depending on the location received by the system and the number of open invoices, the number of users travelling on a specific highway can easily be calculated. This information can be used to identify congestions and would be beneficial for traffic management purposes.

Another effective factor on pricing is weather conditions. The traffic of highways will increase on a snowy day; therefore, the price should vary accordingly. This price is calculated based on the weather conditions and would also be adjusted depending on the time and day of the week [33]. Moreover, the air pollution is the most important factor that should be considered in the toll pricing in Tehran [34]. The air pollution of the highway will be received from its related region and, based on the day and time, the calculation factor and its price will be extracted. The mileage is the traveled distance by each car, which can be calculated by using GPS.

GPS is a system that navigates with a group of satellites. The GPS receiver determines each car distance to some of these satellites and then finds the exact position of car on the ground.

In fact, the basis of this system is to transmit high-frequency radio signals that determine the time and location of the satellite relative to Earth, and a GPS receiver on the ground processes this information by using three or more satellites. Moreover, it shows the user's location anywhere on earth, at any hour of the day and in any weather. With several multiple measurements, the receiver calculates the speed, the travel time, car distance to the destination, the geographic coordinates (latitude, longitude and altitude), sunrise and sunset times (in the astronomical calendar), and provide it to the user. The obtained information can be used in pricing of the taxes and tolls. Finally, the basic price of the highway per kilometer can be calculated based on the formula (1):

$$\textit{Cost (charge)} = \textit{Base price} * \textit{mileage} * \textit{distance} * \textit{vehicle type} * \textit{traffic volume} * \textit{weather conditions} * \textit{air pollution factor} \quad (1)$$

The calculated price will be recorded on the user's invoice and its status will be changed to a value of one, indicating that the user has left this highway and the relevant cost has been calculated. At that stage, the user will have 24 hours to charge his/her electronic wallet. After this period has elapsed, the account will be checked for the requested charge. If the amount has been paid, the status will be changed to two; otherwise, a value of three will be assigned, alerting the traffic police to issue a fine.

3.4. Evaluation of the solution

In this section, the proposed solution is evaluated. Since the other comparable systems in this study are hardware systems which cannot be easily accessed, the comparison of systems in practice is not possible. Therefore, in the first section, the correct performance of the implemented hardware system is evaluated and in the next section, the software solution is evaluated by coding a simulator that measures the transmission and performance of sample data.

- *Evaluation of the hardware system performance*

The GPS/GSM based hardware system's task is to receive the user's real-time location and send it to the server. To test its performance, the system was experimentally installed on a private car for a week and it recorded around 4846 locations and sends them to the server during different tracks. By reviewing the gathered information from the system it became clear that the function of the hardware system is accurate in reporting the location and speed of the vehicle; however due to the requirement of receiving information from GPS satellites and connecting to the GSM network, the gaps between sending and receiving data may vary (become longer or shorter). Therefore, we cannot be sure that the information will be sent to the server every 30 seconds. However, this is not a problem for the system, because only a location needs to be sent to the system at the time of entry and exit of the car in the highway; and in the software, it is predicted that the time of entry and exit of the car will be determined based on the traffic and speed of the vehicles.

- *Evaluation of the software system performance*

In order to evaluate the software system, a motion simulator system was developed for evaluating the performance since the implementation of the system was not possible in large numbers. Since, the polygraph structure of Tehran's highways is not defined, three highways of Shahid Sattari, Shahid Bakeri and Sadr, were defined manually in the system. To evaluate this section, the Cedar Map service was registered to check the system's proper performance and its logs. Ultimately, the system was fully functional in this section. To calculate prices, the price information for each of the elements including the distance, weather conditions, air pollution, traffic, vehicle type and base price for each highway was manually entered into the database.

The performance of the simulator system is in such a way that two points in Tehran are selected randomly and the driving path between them is determined. This route is divided into different points in which the car will change the street or the highway. Subsequently, it will be checked whether these points are on the mentioned highways by sending the initial and the end location of each of these points to the implementation service. The mentioned algorithm in the software solution will be performed in this section, and ultimately the final price will be calculated. The performance of this simulator was evaluated for 150 starting points and destination in Tehran, resulting in a total of 3738 different locations along the traveled routes among which 27 tracks passed through the defined highways in the system, in which all the information was properly stored and prices are fully calculated.

3.5. The Proposed Solution Comparison

In this section, the proposed system is compared with other existing systems. The prime factor to which the system will be measured is the accuracy of the cost calculation. In this section, the proposed system is compared with the two dedicated short-circuit communications systems and the VPS system. For this comparison, information of 10 cars was registered into the system and the system was simulated for 10 days. Finally, the available data in terms of computational accuracy with regard to Sedar maps services were investigated. The results are shown in comparison to the existing systems in Table 2.

The reason behind the reduction of accuracy in identifying in all systems at high speeds is that the short-circuit communication system at the high speeds has a weakness in obtaining information. The proposed systems and the VPS system has a weakness at fast exits because as the gaps between sending location is larger. The proposed systems and the VPS system has a weakness at fast exits since the larger the gap between sending location becomes, the greater the possibility of entering and leaving a user from one interval to another would be. This requires more robust telecommunication equipment, which is not cost effective. The cost of the proposed system is high due to the cost of module installation on all cars and also the cost of infrastructures such as cameras and infrared readers. The difference of the system with the VPS system is also due to the mapping of the user's location to the nearest highway entrance. Moreover, given the fact that the VPS system uses the real-time position of the user for calculating the cost, the proposed system has more accuracy and closer results to the reality.

The next comparison is to analyze the fuel consumption in the proposed system compared to the traditional system. According to the statistics, each vehicle annually spends 6-hour in toll traffics on average [35]. If we assume that 1000 cars per day pass through the gate with the help of the non-stop system, 0.36 million vehicles will pass through toll gates per year without the need to slow down and stand in traffic.

If it is assumed that every car consumes only 2 liters of gasoline during every 6 hours [36] which means the consumption of gasoline will decrease by 720.000 liters per year, which will save up to 7.2 billion Rials per year (1liter = 10000 Rials). This means that the fuel consumption will be reduced by 7.2 billion Rials per year compared to the traditional one-year system for just a number of 1,000 vehicles. It is obvious that the number of vehicles would be much higher on urban highways. The result of the comparison between the suggested solution and the existing systems are shown in Table 3.

4. Discussion & Conclusion

Electronic tolls on urban highways will be one of the major needs of the metropolitans in the upcoming years, as it will control traffic and air pollution, and will provide large revenues to municipalities for future developments. Therefore, Tehran should use this advanced urban structure. Based on the studies, it became clear that different countries, based on their own culture, users' approaches in using different systems, and direct or indirect access of drivers to the Internet, use different combined models to achieve maximum efficiency. Considering the Iranian people's culture, the interest of people in law aversion and non-payment of taxes to the government, and based on existing infrastructure in the country and ways to access the Internet, a model based on dynamic pricing was considered. In addition, a product consistent with the requirements of the Iranian market was prepared which can be used to control the traffic of Tehran as well as toll stations.

The system designed in this study has been adapted to the Iranian culture, infrastructure and urban requirements in Tehran. In addition to being used on highways for tolls, the proposed system, also used in urban areas for traffic plan locations and to receive traffic plan sums. According to the results, this system has high efficiency and reliability compared to other hardware systems. Also, the proposed solution is fully consistent with dynamic pricing based on the elements that influence urban decision making, resulting in precise pricing according to the desired elements in this matter at any given moment. The proposed solution is innovative compared to other research methods in three different perspectives: hardware integration, dynamic pricing, and productivity and reduction of image processing burden. In all of the systems studied in the papers and all the combinations carried out in different countries, GPS/GSM devices, surveillance cameras, and infrared devices had never been put together. In addition, none of the software and hybrid solutions had considered elements such as air pollution, weather conditions, traveled distance, and the days of the week as factors affecting dynamic pricing; while, it is clear that these factors are significantly influential in the construction, use, and maintenance of urban highways.

Adding the infrared module and designing its analysis method and direct connection to the surveillance cameras only pursued one goal, which was to reduce the number of captured images and thereby reduce the image processing burden. The process of converting the image into a text requires a huge amount of processing that puts a huge load on the system. Moreover, processing the images requires advanced processing servers. Therefore, if vehicles become smart and the chips are installed on them, there is no need to use infrared; however, until then, the use of infrared is necessary. Due to the high cost of production, as well as the lack of time and the need for a production line to produce the device on a large scale, it was not possible to produce and test the product on a large scale while the chosen approach in the study was a constructive approach. As a result, the evaluation of the system was performed on the simulated data.

The full implementation of the infrared receiver section in the proposed approach requires about 100 modules, and it is possible to test the section in a laboratory environment, which was also not possible in this study. In addition, the implementation of E-wallet services requires a payment gateway, which is limited to commercial projects in Iran; therefore, it was not possible to implement the E-wallet structure in this project as well.

The main purpose of this research is to use the proposed strategy and focus on the entry point of the system. In other words, the chief objective was to propose an innovative approach for installing devices on users' vehicles in Tehran, based on the resident users of the province. This issue was not considered in this research since the subject of design and implementation was broad, and it is suggested for future research. Another important issue is to address the concerns of users about the violation of their privacy through transmitting users' vehicle locations to a government system. This subject requires reviewing privacy laws and providing solutions to be further discussed and analyzed in the Islamic Consultative Assembly.

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Captions

Table 1. Combined Solutions for Smart Payments in Different Countries
Table 2. Comparison of the accuracy of proposed system with the existing systems at different speeds
Table 3. Advantages and Disadvantages of the Proposed Solution Compared to Existing Systems
Figure 1. Schematic Structure of the Proposed System
Figure 2. The Process of the System Implementation at the Highway Entrance
Figure 3. The Software System Function
Figure 4. The Final Output of the Hardware System

Tables

Table 1. Combined Solutions for Smart Payments in Different Countries

	VPS Technique	Dedicated Short-circuit Communication	Video Tolls	Radio Frequency Identification Unit Technique
Canada			*	*
Italy	*		*	
Singapore		*	*	
USA			*	*

Table 2. Comparison of the Accuracy of Proposed System with the Existing Systems at Different Speeds

Speed	1-30	31-60	61-90	91-120	+120
Dedicated short-circuit communication system [34]	100%	95%	87%	85%	84%
VPS [36]	97%	94%	90%	87%	86%
Proposed System	98%	95%	92%	90%	88%

Table 3. Advantages and Disadvantages of the Proposed Solution Compared to Existing Systems

	Proposed Solution	VPS Technique [38-39][33]	Dedicated Short-Circuit Communication [25]	Video Tolls [22][37]	Radio Frequency Identification Unit [23]
Implementation process	High complexity	High complexity	High complexity	Basic	Basic
cost	High	High	High	Average	Low
Need to stop	-	-	Available	-	Available
Accuracy in identification	High	High	Average	Average	Low
Access to the Vehicles' real-time information	Available	Available	-	-	-
Reliance on the user	-	Available	Available	-	Available
Reliability	High	High	Average	Average	Low
Possibility to use dynamic pricing	Available	Available	-	-	-
Entry Period	Available	Available	Available	-	Available

Figures

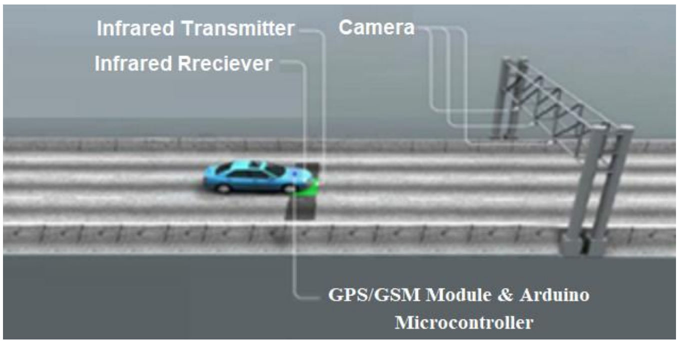

Figure 1. Schematic Structure of the Proposed System

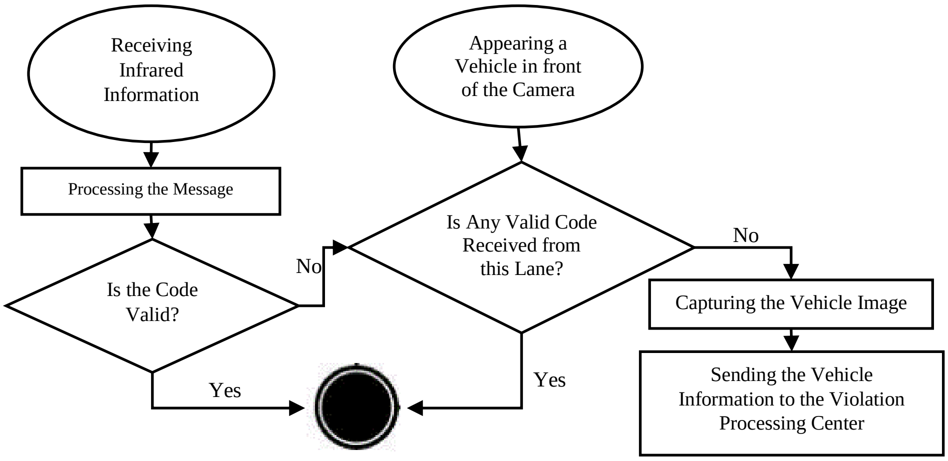

Figure 2. The Process of the System Implementation at the Highway Entrance

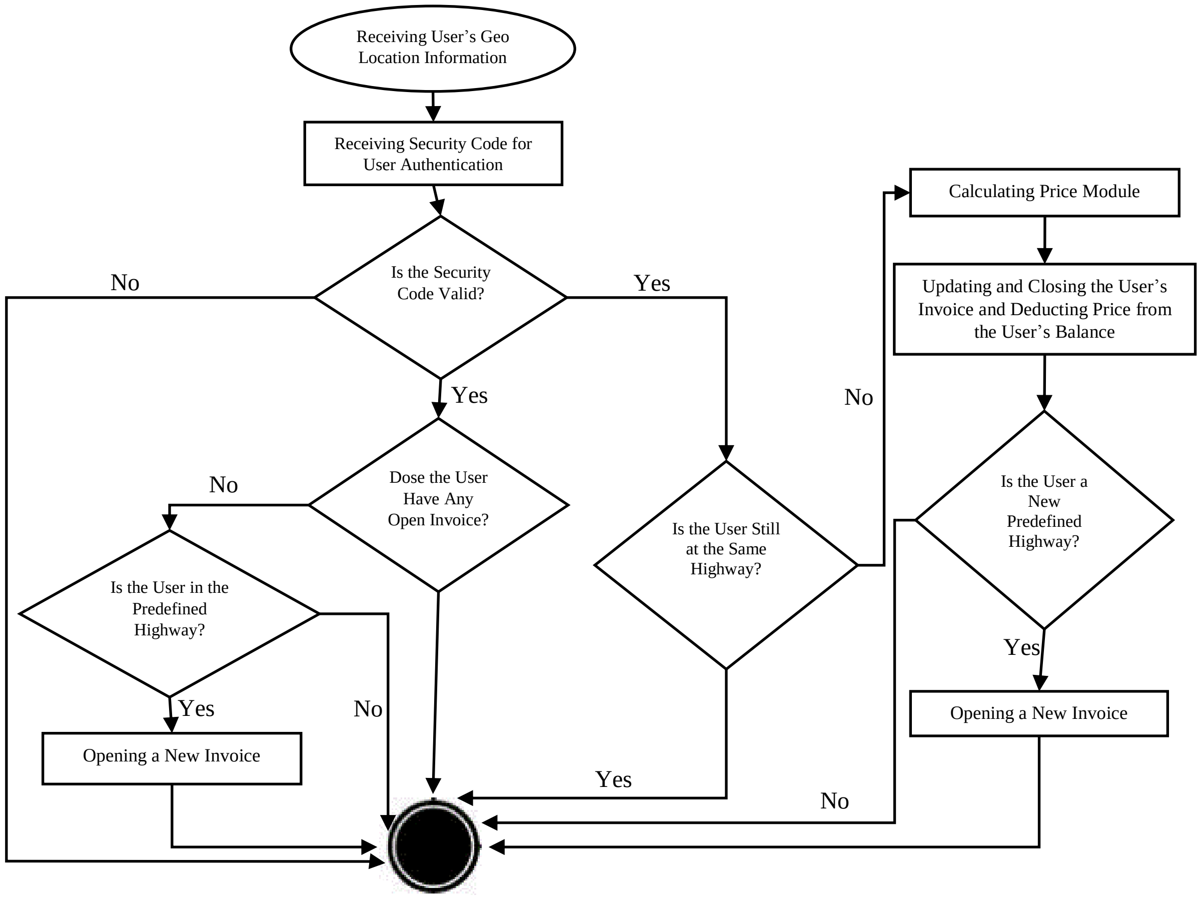

Figure 3. The Software System Function

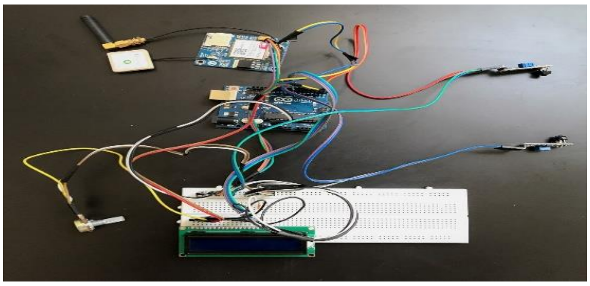

Figure 4. The Final Output of the Hardware System

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