Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 4 Issue 9, September - 2017

An Embedded Vehicle Tracking Application with Dead Reckoning and Assisted Global Positioning Methods

Sadık Arslan, Ercüment Türk
Research and Development Department
Kent Kart Ege Elektronik A.Ş.
İzmir, Turkey
{sadik.arslan, ercument.turk}@kentkart.com.tr

Mustafa Gündüzalp
The Department of Electrical & Electronic Eng.
Yaşar University
İzmir, Turkey
mustafa.gunduzalp@yasar.edu.tr

***Abstract*—In this study, vehicle tracking with dead reckoning and assisted global positioning applications were materialized for an embedded system. GSM modules and GPS modules which allow for tracking the vehicle operation were used in the system. Position information is very important for public transport system, fare collection, determination of the transport route for calculation of system cost and restoration. Disadvantages of GPS and defects caused by nature of this technology were resolved with Dead Reckoning and Assisted GPS methods. Errors in the GPS data were fixed by using online and offline Assisted GPS technology. GPS performance was improved with offline Dead Reckoning. In the design of the developed system, Linux operating system was used. Required Linux operating system peripheral drivers were developed. To realize peripheral module tests, necessary test and user applications and user libraries were written. User applications that provide vehicle tracking were designed for the Linux operating system.**

Keywords—Embedded systems; vehicle tracking; assisted GPS; dead reckoning; Linux operating system

I. INTRODUCTION

A processor that may be considered slow, a memory and other auxiliary units are generally used in embedded systems. In these systems, many operating systems such as Embedded Linux, JavaOS, LynxOS, Mobilinux, and Windows CE are used.

Being a general term, Global Navigation Satellite Systems (GNSS) is the general name for positioning services. These services are developed by different countries and organizations and the facilities and qualities they offer are shaped within the framework of these services. Advancing technology caused these services to enter all fields of life and even have an important part in the end user's life. Positioning and direction finding systems are matters on which much research has been made for centuries and a large number of techniques and methods can be mentioned. Fast advancement of technology has also affected the solutions in this field visibly. Sailors who used to try to determine their directions in open seas by observing rock pieces or celestial bodies many centuries ago can easily find their immediate positions today by palm-sized positioning devices with very small error rates. Apart from these, these systems are used to determine the position, speed and route information in air, land and sea transportation. In addition, the altitude information obtained via these services can be used in any kind of geophysical practices.

Global Positioning System (GPS) of the United States, Global Orbiting Navigation Satellite System (GLONASS) system of Russia, GALLIEO System of the European Union, BeiDou System of China and IRNSS System of India can be given as examples to GNSS systems. The rise in GNSS networks and advancements in modulation techniques increase accuracy in position calculations.

Vehicle tracking systems are a specialized field of embedded systems. These are the systems that show the position of the vehicles on the earth. A processor that can be considered slow, a memory and other auxiliary units such as Global System for Mobile Communications (GSM) module and GPS module are generally used in embedded vehicle tracking systems.

Basically, information is sent by a device that is mounted on the vehicle and determines its position on the earth to the central server and this information is processed in the center. In this way, information such as where the vehicles are positioned at which hour and at what speed they go while moving can easily be seen. All improvements in a vehicle tracking project have been applied both in terms of software and hardware with this project developed.

The system ensures tracking of the vehicle by sending the position information periodically to a server. The position information is generally sent to the server by using a GSM infrastructure. Smart phones, which are used quite widely today, can also be used in different sections of vehicle tracking systems [1 -5]. There are also systems that use GSM [6], Zigbee [7, 8] and wireless sensor networks [9] instead of GPS to find the vehicle positions in the systems. It should not be reckoned that vehicle tracking systems are used only in land vehicles such as cars and buses. Applications are also available in submarine [10] and air vehicles [11]. Vehicle tracking systems are also used in vehcile theft tracking systems [12], logistic fleets [13], traffic accident emergency rescue systems [14], and speed control systems [15]. Durable design is quite important in devices used in vehicle tracking systems.

II. Global Positioning System

GPS refers to special satellite networks designed to determine a position on the earth at any time, place and weather condition by using the distances between the user and satellites through encoded data exchange between the user and specially designed satellites. This system allows the user to obtain the 3-dimensional position and time information at any time.

There are 24 GPS satellites and they revolve around the world twice in 24 hours. These 24 satellites form 6 groups in total. All of the satellites that belong to a group can be seen from any place in the world at any time. The satellites draw the energy needed for their movements from the solar panels and spare batteries on them and run smoothly under challenging circumstances. Maintenance works of satellites are performed in line with the previously-specified plans.

A. Positioning

GPS satellites create 2 different types of very low-power signals. Carrier frequencies of these signals, which are called L1 and L2, are 1575.42 MHz and 1227.60 MHz respectively. Code, phase and orbit information have been modulated on these carrier wave frequencies. The satellites transmit the navigation information continuously to the receivers with the help of these signals. Being a signal with a 50 MHz band width, the navigation information includes such information as GPS system status, hour and satellite information.

Position calculation is actually based on a simple principle. The position of a point can be calculated if its distance to three points with known positions is known. If the distance of a point is known according to an object, the point is a one on the sphere that will be formed by taking the object as the center. If the distance of the point is known according to two objects, this time the point is found on a ring where the two spheres intersect. Finally, if the distance of a point according to three different objects is known, the point can be on two points where three spheres intersect. Only one of these two points can be located on the earth [16].

Information required for position calculation is available in the message content transmitted by GPS signals. The receiver can both predict the satellite position by using these signals and the distance among satellites through a calculation made based on time of arrival of the signal. However, this prediction may lead to variability and errors. This matter will be handled in the following chapters. If the time of arrival of the signal is multiplied by speed of light, the distance between satellite and the receiver can be calculated. The distance to the three satellites seen is calculated in this way. 3 satellite data is required in order for the receiver position to be calculated three dimensionally. In addition to these, time synchronization between the receiver and the satellites is also one of the possible errors. This is remedied with an additional satellite signal. For this reason, at least 4 satellites are required for precise position calculation. [16].

B. GPS Error Sources

There are many interferences and error sources in positioning by GPS. A great majority of these interferences does not generally constitute a drawback in navigation applications, but behaviors of errors have critical importance in military projects and scientific studies and they need to be corrected.

Receiver clock error is the one with the biggest share in GPS errors. GPS satellites are equipped with atomic clocks for accurate measurement, which means very very little deviation in long years. However, it is practically not possible to use a similar clock on the receiver's side. This leads to time deviations on the receiver's side and therefore, synchronic problems with the satellites. This problem is such immense that, for example, one millisecond synchronic loss results in an error of thousands of kilometers. On the other hand, this problem is solved by updating the receivers' own clocks with the time information that comes from the satellites.

Another temporal problem is determining the accuracy of satellite hours. This challenge is kept under control by the control centers located at certain points constantly with multiple atomic hours in the satellites. In this way, this affect is minimized to an ignorable level.

The position information received from satellites gives the mathematical position of a satellite to the receiver. However, this position deviates from the required ones because of the gravity forces of and radiation emitted by the Earth, Moon, Sun and other celestial bodies. The information on the positions they should have is transmitted to the satellites periodically. The difference between the positions they have in satellites and the ones they must have is called the ephemeris error.

Another error source is atmospheric effects. While reaching the receiver, GPS signals pass through different layers of the atmosphere. Electron density, refractive index and therefore, scattering properties of these layers are different. This impacts propagation speed of the signal. Moreover, weather events, pressure, humidity and temperature also disrupt characteristics of the signals.

The circuit characteristics on the receiver's side and software quality are two of the other big error factors. For this reason, especially antenna design and circuit material choice and design bear vital importance in terms of performance.

Multipath fading effect is also one of the most frequently-encountered problems. In this case, the same signal hits the structures in the vicinity such as buildings and reaches the receiver through different paths.

C. Assisted GPS Requirement

GPS users always wait for immediate position information. However, this information is not possible to be obtained with standard GPS all the time. The reason is that orbit information needs to be acquired by the GPS receiver from at least four satellites so as to create sensitive position information. Depending on environmental conditions, weather conditions, existence of signal cutting or signal interfering structures in the vicinity, data transmission from the satellites to the receiver may take minutes or even result in complete failure.

Another disadvantage of classic GPS technology is that it tries to find a position without any information on the coordinates of the initial position held when the GPS receiver is turned on the first time, which is called the Cold Start. This process may take minutes. This delay may take even longer in case of existence of signal blocking effects such as high buildings, snow or tree or other elements that reflect satellite signals. This loss of time is not only affected by environmental factors but technological standards also bring about time loss. The reason is that transmission speed of GPS satellites is 50 bps. As it is required to read a frame of at least 1500 bits in order to read meaningful data from a satellite, no less than 30 seconds need to pass to acquire meaningful data (position, hour) from only one satellite. Since this frame needs to be read from at least four satellites for clear position information, a delay of two minutes only for start seems quite ordinary. Choosing four satellites from tens of them is another source of delay.

All of these situations demonstrate that wireless services such as GSM/GPRS or digital terrestrial broadcast services can play an important role in positioning. Information such as the one on visibility and whereabouts of satellites can be transmitted to the GPS receiver by the GPS data to be provided by a wireless auxiliary method that can work in parallel with the GPS receiver. These methods constitute the Assisted GPS (A-GPS) technology.

Assisted GPS may be offline or online. In both cases, position and time information is presented to the GPS receiver for a faster first fix via the Internet connection [17]. In this technology, GPS information is received via the Internet from a main center by service providers that render this service or a method recommended by the GPS receiver company. A device with a GPS receiver and Internet connection- in this example a mobile phone- receives GPS data from a different server via Internet connection while performing positioning using the satellite signals with GPS receiver. The same working principle can also be applied offline. In this case, measurements can be performed by downloading the satellite information periodically from the Internet. The structure described is shown in Figure 1.

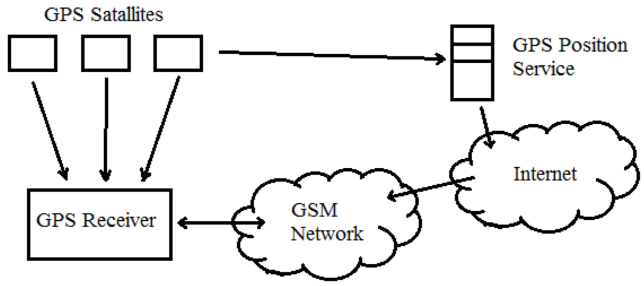

Fig. 1. *Assisted GPS operation chart.*

D. Offline Navigation Calculation Methods

The biggest disadvantage of position prediction through satellite signals is the failure to calculate the positions due to signal cut experienced owing to tunnels, bridges, subways or tall buildings.

At least 4 GNSS satellites need to be seen in precise position calculations. Precise position can be calculated only with the data acquired from these 4 satellites. The level of the signal sent from a satellite that is approximately 20000 km away from the ground drops hundreds of times below a typical Wİ-Fİ signal power until it reaches the receiver. This causes blockage of or failure to use these signals under urban circumstances.

Smart offline algorithms are developed to help the traditional positioning services for the solution of this problem [18, 19]. To this end, GPS receivers have been equipped with tachometer reading feature in order to determine speed of the vehicle and accelerometer and gyroscope features to learn the direction, acceleration, wheel speed and position of the vehicle when position information on the vehicle cannot be obtained. In applications of higher levels, receiver modules were connected to the Control Area Network (CAN), which enabled necessary information to be obtained.

E. Prediction of Distance

There are many ways to measure the distance covered by the vehicle. The simplest of them is finding the number of cycles completed by the wheel in total when a signal produced for a full turn of a wheel is counted by a receiver module through a simple odometer system and the distance can be calculated by using the wheel diameter.

F. Prediction of Direction

Direction can be determined by an accelerometer on a receiver module or an entry entered to the receiver. In order to find the direction precisely, the most correct direction prediction is performed by taking the information on acceleration and distance covered into account. Furthermore, position of the vehicle in the space is found clearly through the data obtained with the help of a gyroscope [20]. Another method is using the angle difference between the left and right wheels.

G. Prediction of Altitude Change

Acceleration and gravity information coming from 3 accelerometers are collected in order to determine the change in the altitude of the vehicle. This information enables calculation of the altitude of the vehicle by for example calculating the inclination of a vehicle going up a slope [19].

The distance taken on a certain axis on a straight road differs from the distance taken on an inclined surface in terms of projection. This causes error in measurement of the absolute distance covered by the vehicle in reality.

The GPS receiver in the vehicle predicts the position, angle and direction of the vehicle by the help of the module and accelerometer and the gyroscope on it. A pulse signal received from a wheel is read from an input port and the distance information is calculated. GNSS packages sent by the satellites are combined with the navigation data by special methods and data on the position, speed and direction data of the vehicle can be obtained in any environment. Structure of the system can be seen in Figure 2.

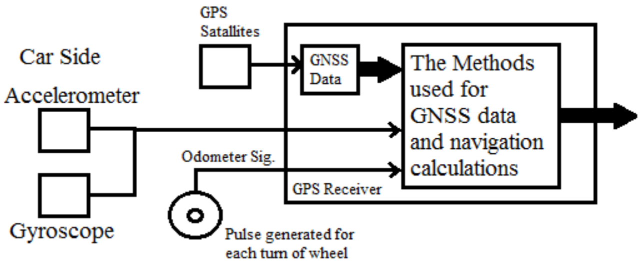

Fig. 2. *Collective use of offline navigation and GNSS.*

III. Architecture and Design of the System

In the developed vehicle tracking system, the basic units are devices that attached to the vehicles and the server in the system center. GPS and GSM antennas are connected to the tracking device on the vehicle. The GPS module in the device forms the position information of the vehicle according to the signals from GPS satellites. The generated information is transmitted to the microprocessor. The microprocessor receives this information and transmits the data to the server by the GSM module. The microprocessor communicates with the GPS module by Universal Asynchronous Receiver Transmitter (UART) interface while communicating with the GSM module through Universal Serial Bus (USB) interface. General simplified structure of the vehicle tracking system can be seen in Figure 3.

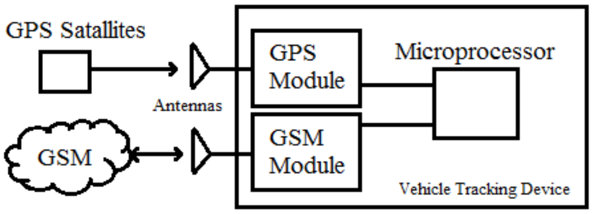

Fig. 3. *Simplified block drawing of the card designed.*

An integrated circuit with ARM core from iMX25 family was used while developing a system. As the system designed was planned to be used in vehicles, energy input in 8 V- 40 V range is possible. In the system filter, which is located at its energy input, voltage fluctuations with a frequency of over 200Hz are filtered and a smooth voltage input is ensured by preventing the noise coming from the vehicle. Input voltage passes through a regulating circuit and 3.3V system main feed is generated. 1.8 V regulator and 5V amplifier circuit were designed in low voltages to e used where necessary. In the system designed, energy of some of the blocks may have to be shut down during operation. For this reason, a mosfet key was added to the 3.3V feed. In this way, some of the blocks are fed from this keyed source.

GPS, GSM and microprocessor make up the main part of the vehicle tracking system. The GPS module communicates with the microprocessor by using UART interface. The satellite signals received from the GPS antenna are calculated in the GPS module and turned into position information. Being in the form of latitude and longitude values, position information is transmitted to the microprocessor through UART. At this point, Linux application developed transmits the position information to the server at the center by using the GSM module. GSM module communicates with the microprocessor by using the USB line. Furthermore, an UART line to be used for different purposes was added for the purpose of communication. The GSM module connects with Subscriber Identity Module (SIM) card. Moreover, GSM antenna was also added for the system's Radio Frequency (RF) connection. Here both the GSM module and the GPS module were designed in a module card each. The GSM module is attached to the vehicle tracking main board by mini Peripheral Component Interconnect Express (PCI-e) interface while GPS module is attached by a connector.

A circuit that is designed to completely shut off the power drawn is present at the input of the system feed. This circuit enables the system to run when the contact signal is received. If the vehicle is stopped, the system designed perceives this through a general-purpose input/output (GPIO) leg. Then, if there is information on itself, it sends this information to the server and energy of the device is cut off with this circuit. Voltage input between 8V and 40V is required for the system. Here voltage fluctuations with a frequency of over 200Hz are filtered in the input filter and a smooth voltage input is ensured by preventing the noise coming from the vehicle. The input voltage passes through a regulating circuit and 3.3V system main feed is generated. 1.8 V regulator and 5V amplifier circuit were designed in low voltages to e used where necessary. In the system designed, energy of some of the blocks may have to be shut down during operation. For this reason, a mosfet key was added to the 3.3V feed. In this way, some of the blocks are fed from this keyed source.

Some blocks such as SPI interfaced memory, Multi Media Card (MMC) that runs with Secure Digital (SD) interface, ethernet interface, Real Time Clock (RTC), and USB interface were used in the project in order for the tracking system to be able to run. Environmental parameters and card serial numbers of the system are kept in the memory which is communicated by SPI interface. Actual hour of the system is found out by using RTC. Battery with a capacity of 2mAh was used so that RTC could work when the energy is cut off. The circuit which gives starting signal to the microprocessor when the system is turned on has also been added to the design. The circuit works as active low level signal and when energy is supplied, it remains at zero for 240 ms and then goes up. In this way, it waits until feed reaches full level and the system is switched on.

The vehicle contact signal, which is 24V upon turning of the key in the vehicles, is required to be used in the circuit. The signal enters the microprocessor and the circuit that contain an optical isolator from here by turning into 3.3V level. By this means, the circuit ensures isolation of the signal in the outer world by this microprocessor. In the same manner, kilometer count signal is also carried to the microprocessor. This signal is produced by the vehicle depending on the distance covered by the vehicle. Obtaining the signal enables calculation of information such as speed of and the path taken by the vehicle. The system can be switched on from the serial port and development works are conducted from UART line. However, communication of the device with the outer world needs to be established by RS232 protocol. For this reason, RS232 converter circuit has been added to the design. Furthermore, it is also desired that the system tests itself. This test mode is different than a normal start. A button that is taken out has to be pressed in order to start test mode. If this button is pressed when the device is powered initially, the device does not start normally and it enters the test mode where all functions could be tested. Controller Area Network (CAN) interface of the microprocessor was used in order to reach CAN in the vehicles. Here CAN integrated converter circuit was used for signal interface compatibility.

Accelerometer sensor, Electronically Erasable Programmable Read-Only Memory (EEPROM), heat sensor and digital potentiometer were also used on the card. These units are checked by I2C interface. Analogue signal input circuits were designed on the card in order to be able to read the analogue signal level from the outer world. The circuits can read the signals between 0V and 60 V in the outer world. 6 signal lines that can be digital inputs and outputs in total -to be used if necessary- were taken to the outer world by a connector. An integrated input output amplifier that runs with a SPI interface was used in order to form these signals. Optical isolator was used for isolation of digital signals. Circuits were designed so that a buzzer and 3 Light Emitting Diodes (LED) are used to give information to the outer world. Simplified hardware structure of the vehicle tracking system is given in Figure 4.

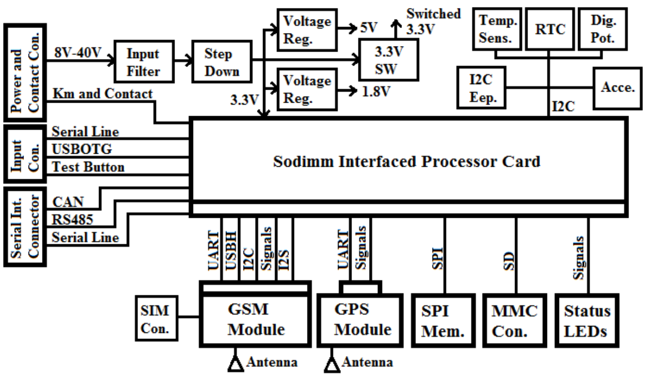

Fig. 4. *Hardware blocks of vehicle tracking system.*

IV. Software Design of the System

Linux Kernel 2.6.35.3 operating system is used in the device utilized in the vehicle tracking system. Vehicle tracking application, power management application, GPS control layer and radio interface layer were developed in the device. The GPS control layer is the application that basically sorts the information coming from the GPS module and gives the location coordinates to the other applications. Radio interface layer application is an interface between GSM (radio) hardware of vehicle computers and Linux operation system and other applications. This interface covers all the procedures that are necessary to make calls, perform data transfer and use the Short Message Service (SMS). Many properties such as being able to access SIM, sending message by using SMS, sending audio and data are supported. This application manages the modem used by using the AT commands. The vehicle tracking application starts the radio interface layer application when data transfer is required and conducts the transmission. The vehicle tracking application interprets the position information coming from GPS control layer. This application information is transmitted to the server through the radio interface layer. User Datagram Protocol (UDP) technique is used in the packages sent. UDP was chosen as it sends messages from one application program to another by minimum protocol mechanism. In addition to the position information, records on the vehicle status are also sent from the vehicle tracking application. Power management application checks the status of the battery in the vehicle in which the device is mounted and prevents it from dying. This application receives contact information from the vehicle. It ensures that the vehicle operates normally while running. In cases where it is not running, it safely shuts downs energy of the whole system and ends operation of the device. Furthermore, this application reads the voltage level of the vehicle battery and sends this to the server as information. Layered structure of device software can be seen in Figure 5.

Vehicle Tracking and Power Management Applications
GPS Control and Radio Interface Layer
User and Kernel Libraries
Hardware Drivers
Hardware Layer of the System

Fig. 5. *Systemic layers of vehicle tracking device.*

The record sent to the database of the system by UDP, which is located on the server's side, is viewed by any web browser. In the imaging system, identity number of the vehicle is entered and all the records in this vehicle are viewed. In the project, the vehicle was also viewed on the map according to the position information of the device through a Web browser. An example to ordering of device records is given in Figure 6.

Vehicle No	Time Stamp	Scope	Description
90015	2017-02-20 08:36:36.739	[0015]TimeUpdate_nt	SysTime from 2017022007
90015	2017-02-20 07:31:18.252	vtctl	contact closed
90015	2017-02-20 07:30:55.201	vtctl	battery: 14.0238880
90015	2017-02-20 07:29:54.055	vtctl	battery: 13.9373210
90015	2017-02-20 07:28:53.908	vtctl	battery: 14.8277250
90015	2017-02-20 07:28:19.897	[0015]SendFile-GPS	FAILURE:1 Active:ppp0
90015	2017-02-20 07:27:52.759	vtctl	battery: 14.8153590
90015	2017-02-20 07:19:44.590	vtctl	battery: 15.3347630
90015	2017-02-20 07:19:22.103	[0015]TimeUpdate_nt	ntpdate err
90015	2017-02-20 07:18:43.450	vtctl	battery: 15.4336970
90015	2017-02-20 07:18:05.724	RILD	GIP 10.233.79.192

Fig. 6. *Records of the tracking device in the server.*

The position of the vehicle on the map is drawn through the map service written according to the position information on the database. In the system designed, the roads on the map and real positions are matched and the route is shown.

A faster solution was proposed by using Assisted GPS technique for the solution of the cold start problem encountered in the system developed within the scope of the project. While position information is acquired, connection is established to the company server from which Assisted GPS data are received via the Internet through the GSM/GPRS module attached on the trip computer. In this application, connection is established with the access providing server instead of the main server provided to the Assisted GPS Data by the module supplier so that a more flexible structure is obtained. The position information obtained is used by an application operating on the server of the access providing company via the Internet and immediate or retrospective route finding and positioning are performed. Similar works are available in the literature [21]. Figure 7 shows the connection to the server from which GPS data are obtained via a Proxy server.

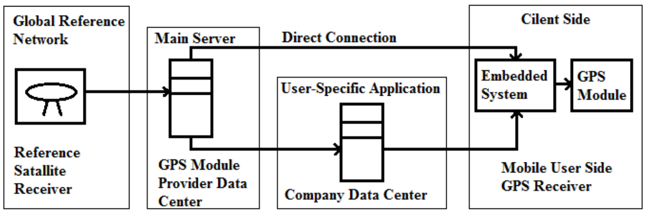

Fig. 7. *The client and intracompany server connections.*

Temporal, almanac and ephemeris information is obtained via the Internet from the service provided by the company's data center or module provider. In this way, initial positioning period of the receiver is shortened considerably and this information is put into use in cases where it is hard to collect the information necessary for the receiver to calculate position.

It has been ensured that position of the vehicle can be found in such closed spaces as tunnels through the accelerometer and gyroscope on the GPS receiver module used. Required hardware connections have been provided to the module so that the direction of and the distance covered by the vehicle can be measured.

In the sample images taken from the web interface of the vehicle tracking system in Figure 8 and Figure 9, deviation attracts attention especially in the areas where satellite signals are interfered. This causes many operational problems. The map images shown in Figure 8 and Figure 9 are some of the problems encountered before the study.

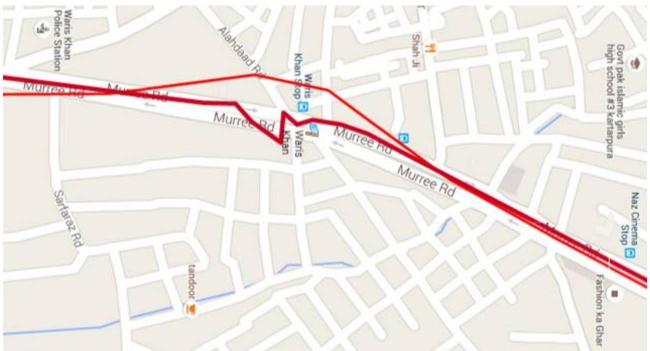

Fig. 8. *Deviation of the vehicle passing from a tunnel.*

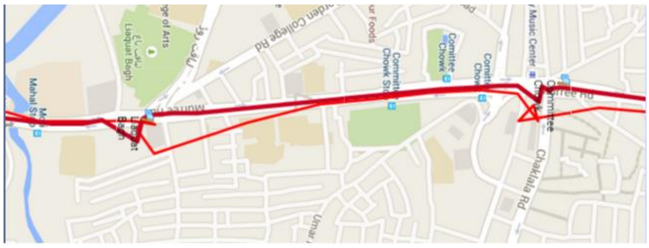

Fig. 9. *Position error for passing over the bridge.*

In Figure 10, no deviation occurred in the position of the vehicle in around 500 examples by the help of the software developed and the module designed after the study.

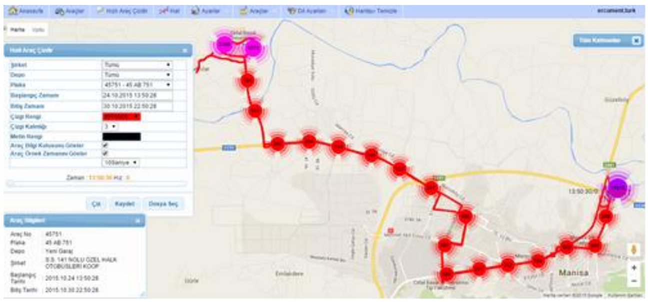

Fig. 10. *Faultless position and route print-out obtained as a result of the study.*

V. CONCLUSION

A vehicle tracking system was designed in line with the pre-project objectives. The devices available in the vehicle tracking system were designed by using a microprocessor. The device was designed and necessary hardware and software upgrading was carried out. Positions of the vehicles on the earth were obtained using GPS and GSM technologies in the system and recorded in the database. Use of the information recorded enabled tracking of the vehicles on the map.

In the vehicle tracking software developed, error rate in the position information calculated by GPS signals was reduced and position information with high accuracy rate was obtained in areas such as bridge, tunnel, downtown that cause cuts and interferences in satellite signals.

ACKNOWLEDGMENT

We would like to thank Kent Kart Ege Elektronik A.Ş. Company for all equipment and laboratory conditions.

REFERENCES

[1] Minni R, Gupta R. Low cost real time vehicle tracking system. Fourth International Conference on Communications and Networking Technologies; 04-06 Jul 2013; Tiruchengode, India. New York, NY, USA: IEEE. pp. 1-5.

[2] Lee S, Tewolde G, Kwon J. Design and implementation of vehicle tracking system using GPS/GSM/GPRS technology and smartphone application. IEEE World Forum on Internet of Things; 06-08 Mar 2014; Seoul, Korea. New York, NY, USA: IEEE. pp. 353-358.

[3] Shinde PA, Mane YB, Tarange PH. Real time vehicle monitoring and tracking system based on embedded Linux board and android application. International Conference on Circuit, Power and Computing Technologies; 19-20 Mar 2015; Nagercoil, India. New York, NY, USA: IEEE. pp. 1-7.

[4] Tahat A, Said A, Jaouni F, Qadamani W. Android-based universal vehicle diagnostic and tracking system. IEEE 16th International Symposium on Consumer Electronics; 04-06 Jun 2012; Harrisburg, PA, USA. New York, NY, USA: IEEE. pp. 137-143.

[5] Şimsek MA, Erdemli T, Tasdelen K. Location detection and data transfer with android smart devices. XV. Academic Informatics Conference; 3-5 February 2013; Antalya, Turkey. pp. 988-990.

[6] Parvez Z, Ahmed KZ, Mahfuz QR, Rahman S. A theoretical model of GSM network based vehicle tracking system. International Conference on Electrical and Computer Engineering; 18-20 Dec 2010; Dhaka, Bangladesh. New York, NY, USA: IEEE. pp. 594-597.

[7] Anuradha P, Sendhilkumar R. Design and implementation of zigbee-RFID based vehicle tracking. International Conference on Sustainable Energy and Intelligent Systems; 20-22 July 2011; Chennai, India. New York, NY, USA: IEEE. pp. 689-694.

[8] Karyemsetty N. Samatha B. Rao KH. Design and deployment of Vehicle Tracking System in VANETs using Xbee Pro: Prototype model. International Conference on Communication Networks; 10-12 Dec 2015; Bandung, West Java, Indonesia. New York, NY, USA: IEEE. pp. 97-100.

[9] Aravind KG, Chakravarty T, Chandra MG, Balamuralidhar P. On the architecture of vehicle tracking system using wireless sensor devices. International Conference on Ultra Modern Telecommunications & Workshops; 12-14 Oct 2009; St.Petersburg, Russia. New York, NY, USA: IEEE. pp. 1-5.

[10] Marquardt JG, Alvarez J, von Ellenrieder KD. Characterization and system identification of an unmanned amphibious tracked vehicle. J. Ocean. Eng. 2015; 39-4: 641-661.

[11] Gray T. Launch vehicle tracking enhancement through Global Positioning system Metric Tracking. IEEE Aerospace Conference; 07-14 Mar 2015; Big Sky, MT, USA. New York, NY, USA: IEEE. pp. 1-9.

[12] Shruthi K, Ramaprasad P, Ray R, Manjunath AN, Shubham P. Design of an anti-theft vehicle tracking system with a smartphone application. International Conference on Information Processing; 16-19 Dec 2015; Pune, India. New York, NY, USA: IEEE. pp. 755-760.

[13] Tekin M, Zerenler M, Bilge A. The influence of using information technologies on the performance of companies: an empirical study in logistic sector. Istanbul Commerce University Journal of Science, 2005; 8-2: 115-129.

[14] Demircan T, Yıldırım S, Yıldız M, Ekşi Z, Çakıroğlu M. Designing of an emergency call system for traffic accidents. SAU J. Sci. 2013; 17-3: 315-319.

[15] Zhu M, Chen H, Xiong G. A model predictive speed tracking control approach for autonomous ground vehicles. Mech Syst Signal Process 2017; 87-B: 138-152.

[16] Zubaroğlu T. An investigation of software based gps receivers. MSc, Hacettepe University, Ankara, Turkey, 2013.

[17] Wong A, Kam W, Lee AT, Xiao X, Luk VW, Cheng KW. An AGPS-based elderly tracking system. First International Conference on Ubiquitous and Future Networks; 07-09 Jun 2009; Hong Kong, China. New York, NY, USA: IEEE. pp. 100-105.

[18] Lee Y, Yu CW, Kim S. Urban localization method for mobile robots based on dead reckoning sensors, GPS, and map matching. IEEE International Conference on Systems, Man, and Cybernetics; 09-12 Oct 2011; Anchorage, AK, USA. New York, NY, USA: IEEE. pp. 2363-2368.

[19] Kalan N, Fang Z, Francisco CP, Jun L. Dead reckoning on smartphones to reduce GPS usage. 13th International Conference on Control Automation Robotics & Vision; 10-12 Dec 2014; Geylang, Singapore. New York, NY, USA: IEEE. pp. 529-534.

[20] Yu Z. Dead reckoning algorithms for indoor localization. MSc, National University of Singapore, Singapore, 2012.

[21] Feng S, Law CL. Assisted gps and its impact on navigation in intelligent transportation systems. The IEEE 5th International Conference on Intelligent Transportation Systems; 6 Sep 2002; Singapore. New York, NY, USA: IEEE. pp. 926-931.