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Development and Performance analysis of a GPS-GSM Guided System for Vehicle Tracking

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***Abstract*— Vehicle theft is a growing menace which poses serious problems in the society. The theft of vehicles affects vehicle owners, insurance companies, security companies as well as the society at large. Tracking devices offer a cost effective and reliable solution to this problem. This paper, therefore presents the development of a GPS-GSM guided system for vehicle tracking. The developed system comprises of an integration of both hardware and software such as a microcontroller (Arduino), GPS module, GSM module, and a vibration sensor. The hardware development consists of wiring between the GPS module, GSM module, Arduino, and vibration sensor. The software development uses Arduino source code, GSM module AT commands, and the GPS protocol command. The system is controlled by the user with the use of text messages. The system uses the correlation between the text messages and programmed keywords to send the vehicle coordinates directly to the vehicle owner or to local authorities. Performance tests show that the system sends coordinates to the owner whether or not the vehicle is in motion. The system is reliable and cost effective for monitoring vehicles in the eventuality of car, motorbike or bicycle theft.**

Keywords*— *Vehicles, Tracking, GSM module, GPS module, Arduino microcontroller.

I. INTRODUCTION

A vehicle tracking system consists of an electronic device installed on the vehicle which relays its position or location to the necessary authorities at all times. Most of today's vehicle tracking systems use the Global Positioning System (GPS) to get an accurate or precise fix on the vehicles position. In addition, components such as cellular (GSM) and satellite transmitters are combined and used to communicate the vehicle's position to the user. The vehicle's information such as current location, past locations, and timeframe can be viewed by using a software on a computer, an application on a phone or a website [1].

Vehicle tracking systems are commonly used by fleet administrators for fleet management functions such as routing, dispatch, on-board information, and security.

Tracking technologies available to fleet managers include mobile tracking, satellite tracking, and passive tracking. Fleet managers use vehicle tracking devices to reduce the insurance cost on the vehicle, because the risk of loss of the vehicle is reduced [2-3]. In asset tracking scenarios, vehicle tracking devices are used to track valuable assets for insurance or other monitoring purposes. Asset tracking is achieved by real-time asset detection on a map for mobile field sales where the parties involved might be in unfamiliar territories. The parties involved can subsequently locate themselves by getting driving directions thereby increasing productivity, reducing drive time, increasing time of interactions with customers, reducing fuel costs, and reducing mileage [4-6].

The rest of this paper is organized as follows. In Section II, the materials and methods employed for the development of the vehicle tracking system is described in detail. The results of the hardware implementation are discussed in Section III. Finally, Section V concludes the paper.

II. RELATED WORKS

This section provides a review of related works. In [7], a vehicle tracking system based on GPS and GSM technology was developed. The components used for the design include AT89C51 microcontroller (MC), GSM, and GPS module powered by a 12V/3.2A battery. A hardware prototype was developed in [8] which used GPS to obtain the coordinates of a vehicle. The main components used in the implementation are: Arduino Uno microcontroller, u-blox LEON-GIOO GSM module, and u-blox NEO-6Q GPS receiver module. The developed system is cost effective, and is accurate in determining the location of vehicles. Authors in [9], presented the design of a vehicle tracking system using a GSM Modem, GPS unit, two relays, and two microcontroller units (MCU). A similar system was developed in [10] to track vehicle locations using GPS technology which incorporated a web platform. In [11], an android OS and GPS tracking system was used for the location of vehicles. Furthermore, a software application was designed with the android OS which was interfaced with google map for accurate tracking of vehicles. This enabled a RFID tag interfaced with GPS and GSM technology to track vehicles and convey goods from one destination to another.

III. MATERIALS AND METHODS

The procedures taken in the development of the GPS-GSM based vehicle tracking system are discussed in detail in this section. The GPS-GSM based tracking system for vehicles is constructed based on optimum material consideration, i.e., locally sourced materials were used to achieve similar efficiencies as their more expensive counterparts. The methodology employed for the design and construction is elucidated subsequently.

A. *Hardware Components*

The hardware materials used for the development of the GPS-GSM based vehicle tracking system are: SIM 800l module, Arduino Uno microcontroller, MCP 602 Op Amp, Resistors, Irlz44n MOSFET, Lm2940CT voltage regulator, Capacitors, Piezoelectric Transducer, Batteries, and NEO 6M GPS module. The list of components used to develop the GPS-GSM based vehicle tracking device are presented in Table I.

B. *System Design*

This section presents the flowchart, block diagram, and circuit design of the proposed vehicle tracking system. The block diagram describes the modules that make up the system as shown in Fig. 1. The Arduino Uno microcontroller processes inputs and sends the corresponding output to the respective modules.

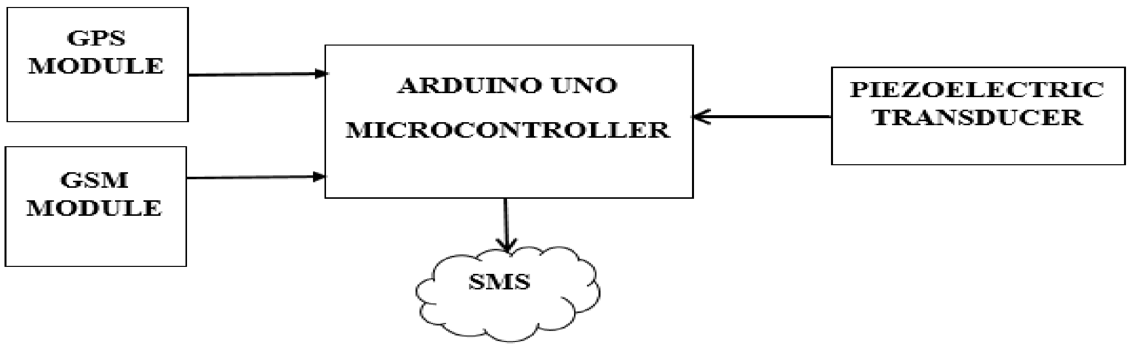

Fig. 1. Block diagram of the GPS-GSM system.

The input to the system can either be from the GSM module in the form of text messages, GPS module or piezoelectric transducer. The output of the Arduino Uno is majorly geared towards SMS transmission.

TABLE I. COMPONENT LIST AND DESCRIPTION.

S/N	Description	Quantity	Unit
1	SIM 800l Module	1	
2	Arduino Uno	1	
3	MCP 602 Op Amp	1	
4	Resistors	4	20kΩ, 680kΩ, 10kΩ, 470kΩ
5	Variable Resistor (pot trimmer)	1	50k Ω
6	LM2940CT Voltage Regulator	1	5V
7	Capacitor	2	220nF, 22µF
8	Piezoelectric Transducer	1	
9	Battery	3	9V, two 3.7V
10	NEO 6M GPS Module	1	

The electronic circuit used to build the system was designed and simulated with Proteus software. The design was then implemented and tested on a solderless breadboard. All the components were tested in real time to ascertain the workability before soldering them on the Vero boards. The designed circuit diagram is shown in Fig. 2.

The systems programming was performed using the Arduino IDE and was uploaded to the Arduino microcontroller using the same platform. The programming language used in the Arduino IDE was C++. After the code was written, it was debugged and tested by simulation using the Proteus Software.

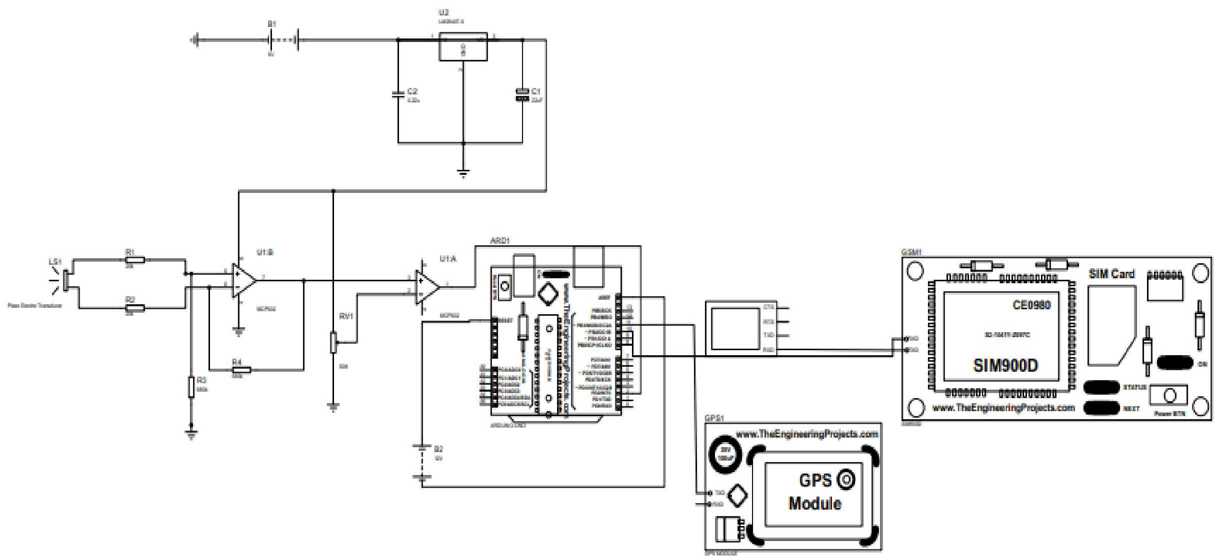

Fig. 2. Circuit diagram of the proposed GPS-GSM Guided System for vehicle tracking.

C. Design Integration

This stage involves the integration of electronic components and mechanical components through the use of commands (programming). The order of module integration is detailed as follows:

i. The GPS and GSM modules were tested by uploading the command to the Arduino microcontroller and interfacing the modules with the Arduino.

ii. The vibration sensor circuit was built and tested on a breadboard.

iii. The GPS module, GSM module, and vibration sensor circuit was integrated into a single circuit and tested; after which it was transferred unto a Vero board and soldered.

iv. The circuit's connection to an external power source was established.

D. System Control

The GPS-GSM based tracking device can be controlled through the use of text messages. When text messages are sent to the system, it responds by sending back the coordinates provided the keywords match. Two keywords were used for the operation of the system which are 'ON' and 'OFF'.

When the user sends a text message with 'ON' as the message body the system is designed to send the coordinates back to the programmed users number. When the user sends a text message with 'OFF' in the message body, this signifies that the vehicle has been stolen and a message is sent to a programmed local authority's number to induce quick action. The coordinates of the vehicle will be sent back to the programmed number regardless of the number through which the message is sent provided that the keywords match either 'ON' or 'OFF'.

IV. RESULTS AND DISCUSSION

Performance evaluation was carried out on the developed system. This includes battery life test, position accuracy test, and time to first fix test.

A. Battery Life

The battery life test involved recording the two batteries voltages for every 5 minutes to test how long the batteries could power the system. Battery 1 supplies a maximum of 9V which is used to power the vibration sensor in the system. Battery 2 consists of two 3.7V Lithium Polymer batteries connected in series. They are used to power the Arduino, GSM module, and GPS module. 3.3V is the lowest voltage that can be supplied by a 3.7V Lithium Polymer battery before it needs to be recharged. Thus, two lithium batteries connected in series will produce 6.6V before it needs to be recharged. For the 9V battery the lowest voltage that can be supplied is 5.4V. The results obtained from the battery life test are shown in Table II. Fig. 3 shows the graph of the voltage against time for battery 1 and battery 2. From this graph, it can be deduced that the batteries voltages decreases linearly with time and are estimated to last for at least 20 hours.

TABLE II. OBSERVED DECREASE IN BATTERY VOLTAGE WITH RESPECT TO TIME.

S/N	Time (min)	Battery 1 Voltage, v1 (V)	Battery 2 Voltage, v2 (V)
1	0	9.00	7.14
2	5	8.87	7.10
3	10	8.85	7.08
4	15	8.81	7.06
5	20	8.76	7.03
6	25	8.55	7.01
7	30	8.45	6.98
8	35	8.15	6.95
9	40	8.05	6.91
10	45	8.00	6.88

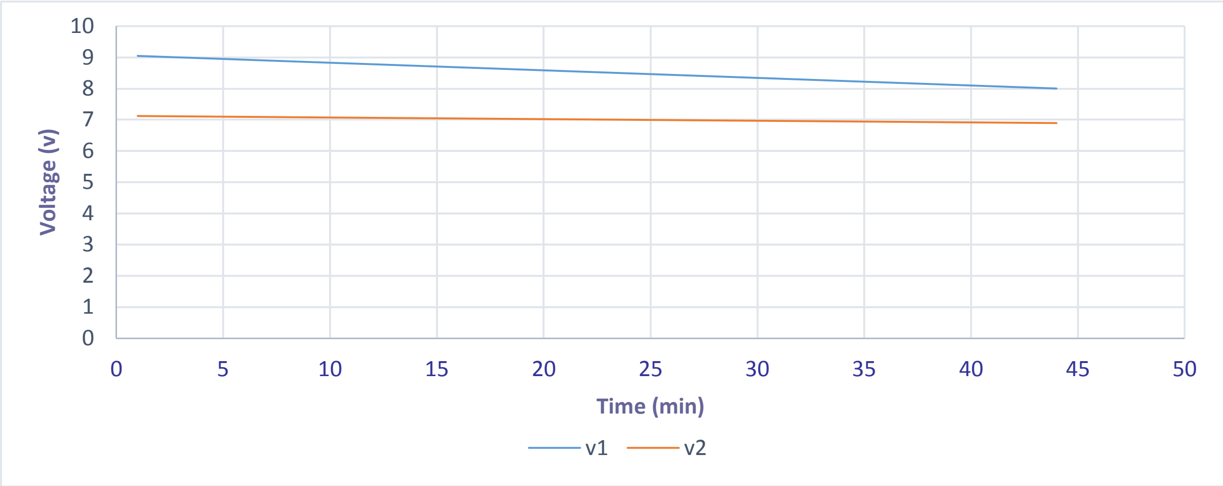

Fig. 3. Battery-voltage time graph.

B. Position Accuracy Test

This test involved measuring the accuracy of the coordinates given by the GPS module under different scenarios or constraints such as bad weather, enclosures, and high rise buildings. Situations involving no constraints included good weather and clear skies (no tall buildings or enclosures within appreciable distance of the GPS). In this test, the coordinates provided by the GPS module were compared to the actual coordinates provided by Google Map and the difference in terms of distance was noted. The test was carried out for 5 different locations and the variation in distance were recorded. The variations in distance were measured using tools provided by Google Map. The results obtained are shown in Table III.

TABLE III. COMPARISON OF POSITION ACCURACY.

Position	Actual Coordinates (Latitude, Longitude)	GPS Module Coordinates (Latitude, Longitude)	Constraints	Variation in Distance (m)
1	7.60431, 5.30762	7.60440, 5.30767	Yes	2.57
2	7.60362, 5.30762	7.60438, 5.30765	No	0.90
3	7.60610, 5.30750	7.60570, 5.30680	Yes	5.00
4	7.60438, 5.30762	7.60438, 5.30763	No	0.69
5	7.60477, 5.30762	7.60441, 5.30765	Yes	3.67

The GPS module (Neo-6m GPS) used has a stated accuracy of 0.50m. Using the obtained results in Table III, the accuracy of the system relative to the stated accuracy can be calculated using:

Accuracy (%) =

$$100\% - \left(\frac{\text{Actual Variation} - \text{Stated Variation}}{\text{Actual Variation}} \times 100\%\right) \quad (1)$$

where:

Stated variation = Accuracy of Neo-6m GPS, and Actual variation = Results of the variation obtained. The results of the comparison of systems accuracy is presented in Table IV.

TABLE IV. COMPARISON OF SYSTEMS ACCURACY (ACCURACY OF THE SYSTEM RELATIVE TO THE STATED ACCURACY).

Position	Percentage Accuracy (%)
1	19.46
2	55.60
3	10
4	72.46
5	13.62

C. Time to First Fix

This test is concerned with the time required for the GPS module to connect to at least three satellites in orbit for the purpose of triangulation. Once the module connects to three satellites it has acquired a fix. The GPS-GSM tracking device can send coordinates once it has acquired a fix. This therefore implies that the systems effectiveness partly depends on the time to first fix. The test involved noting the time to first fix for the GPS module for 5 different locations. The results are shown in Table V.

TABLE V. TIME TO FIRST FIX COMPARISON.

Location	Time to First Fix (TTFF) (minutes)
Position 1	4.00
Position 2	1.45
Position 3	2.60
Position 4	3.45
Position 5	2..00

The developed GPS-GSM based tracking system compares favourably cost-wise to existing or popular tracking devices and is very convenient for small-scale use.

The systems performance in terms of position accuracy is dependent on various factors such as bad weather, enclosures, and high rise buildings (constraints). The existence of such constraints can give rise to errors in the systems readings. The errors produced vary depending on the type of constraints. For example, the error produced by the system in an area that is densely populated by high rise buildings will be larger than that of an area with a few high rise buildings. The accuracy of the developed GPS-GSM system can also be affected by other factors such as satellite clock, orbit errors, multipath, and satellite geometry relative to the user. However, in cases where there were no constraints, the system is highly accurate.

The startup up time for the system which is the Time to First Fix (TTFF) varies. From the test carried out, it was observed that the TTFF becomes shorter when the system is restarted in the same position or at a position near the preceding position. This is because of the memory stored from the last fix. It was also noted that the TTFF and position accuracy improved when the system was near a cell tower (Assisted GPS). For the developed GPS-GSM system, the system took at most 4 minutes to gain a fix while at least 1.45 minutes to gain a fix. It was also concluded from the test carried out, that the system could lose its fix while in motion temporarily for at most 10 seconds due to orbital movement. The battery of the system was tested and was observed to last for at least a day on full charge. Fig. 4 shows the developed GPS-GSM based tracking system for vehicle detection.

Fig. 4. The developed GPS-GSM based tracking system.

Whenever the vehicle starts moving or when the user requests for the coordinates by sending a text message to the system, the GPS-GSM system sends the coordinates of the vehicle location. When the user requests for the coordinates, the system sends a text message back to either the user or the local police depending on the predetermined programmed keywords used in the text message. Whenever the vehicle is parked or stationary, the GPS-GSM tracking system does not send any coordinates. In cases where the car is dismantled in an obscured place, the GPS-GSM system will still send coordinates if requested by the user as far as the system is not destroyed. The Arduino Uno (microcontroller) was interfaced with a GSM, piezoelectric transducer, and GPS module in order to achieve this task.

V. CONCLUSION

A GPS-GSM based tracking system for vehicles was designed and implemented in this paper to send text messages with coordinate information remotely.

The developed system was made portable for security purpose. A wireless module was fitted to make the system fully smart and to communicate as an 'Internet of Things' device. An efficient vibration detection mechanism was integrated and the system performed effectively under different modes of operation.

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