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Design and Development of a Low Cost Ubiquitous Tracking System

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Abstract

In this paper, design and development of a ubiquitous tracking system is proposed, in which vehicles are tracked and controlled using the prevailing cellular technologies. The system contains a GPS receiver and a GSM modem interfaced with a microcontroller. To track any vehicle, the vehicle's owner has to send an SMS to the tracking system installed inside the vehicle. Upon receiving the SMS, the microcontroller takes the current location's longitude and latitude coordinates from GPS receiver, packs it into an SMS and sends it to the owner and on a web server using GSM modem. When the web server receives the SMS containing vehicles coordinates, it will show location of the vehicle on Google Maps. For android users, the location is also displayed on an android application. In case of vehicle theft, the owner is able to turn off the main ignition switch, check status and speed of the vehicle simply by sending an SMS. The system is also equipped with a special security button for parked vehicles. By turning the button ON, the system will come in ACTIVE mode and will keep a special check on the vehicle's movement meanwhile performing the normal tasks. If the system senses any movement of vehicle during the ACTIVE mode, it will turn the main ignition OFF and will inform the owner immediately by sending 5 SMSs. Record of the vehicle's movement will be continuously managed on the web server where each owner will have vehicle's account. We have used a wide number of technologies including, but not limited to, Global Positioning System (GPS), Global System for Mobile Communication (GSM) and Microcontroller.

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1. Introduction

Global Positioning System (GPS) tracking systems play an important role in the position aware applications¹². Global positioning satellites network is known to have offered users a number of services and application especially in the field of tracking. It can also be used in tracking the distance travelled on a trip, vehicle mileage, and speed. It can

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keep the record of driving activity, including address of each destination reached and the length of stay. Today, there exists a lot of tracking systems but that facilitate a user with limited services. Along with the facilities, a ubiquitous navigation and tracking system must satisfy the following performances: scalability, integrity, portability, usability, precision and uninterrupted service.

Interestingly, there are a number of GPS devices offering a number of amenities. However, their cost is significantly high in contrast with their performance and facilities offered. Consequently, investing in these systems costs a lot which motivates the need of design and development of cheaper as well as high performance systems.

As per 2013 report of Pakistan Telecommunication Authority (PTA), there are over 129.6 million mobile phone subscribers¹⁴ and over 14.4 million Mobile Internet Subscribers (GPRS, 3G, and WAP)¹⁵ in Pakistan which brand it a gigantic marketplace for initiating an expedient application such a GPS based tracking system of mobile assets. There already exists tracking systems but these systems are, firstly, too expensive to be taken advantage of, secondly, not user friendly, and thirdly, none of them exploit the capability of a mobile device to provide tracking through GPS. For that reason, customers of such systems need to buy additional devices to get a tracking service. Also, in most cases, the user is not given the authority to track his/her own vehicle and has to consult the company to track the mobile assets indirectly. This delay of service is larger enough to, lets say, for thieves to robe the asset successfully. On the contrary, mobile phone users could easily find an application that offers GPS tracking on the internet but in most cases, such systems have limited functionalities or their functionalities are not free. So, the need of a low cost, powerful and high performance GPS based tracking device is emerging in order to provide full security to mobile assets and keep the track of its movement.

Rest of the paper is organized as follows: section 2 presents the related work, while Section 3 presents the motivation. Overview of Proposed System design is described in section 4. Section 5 presents the Results and Analysis, and finally, section 6 concludes the paper.

2. Related Work

Due to the increasing need of security, a number of tracking systems have been proposed, designed and implemented. Authors in⁴ introduces an efficient approach for mobile asset tracking using contexts. The aim is to develop an efficient and improved geographical asset tracking solution and conserve valuable mobile resources by dynamically adapting the tracking scheme by means of context-aware personalized route learning techniques. A novel light sensor based information transmission system for indoor position and navigation has been presented in².

Implementations of tracking systems have been presented in⁵ and⁷. The work included theoretical explanation of system and failed to present a hardware system and its working. In⁶, authors introduced an integrity monitoring algorithm based on ultra-tight configuration. They also used Kalman filter residual based on the ultra-tight filter to find the test statistics.

Authors in⁸ propose and implement a low-cost GPS tracking system. The system provide user with real time monitoring but it fails to be an independent tracking system because it uses GPRS and SMS gateways. In⁹, authors proposed a ubiquitous vehicle tracking and management system. They provide two types of end user application, a web application and a mobile application. However, they are also using SMS gateways for transmitting message, and GPRS for uploading data on internet which is unreliable. The system may crash if the SMS gateway and GPRS is blocked, so, the system is totally dependent and is not standalone.

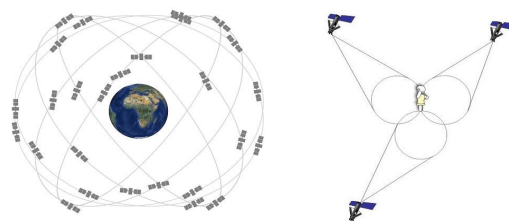


Fig. 1. (a) GPS Satellites around the earth (b) Trilateration Position

A wireless sensor networks for pilgrims tracking is presented in ¹⁰. The communication between mobile units and the sensor nodes relies in IEEE802.15.4/Zigbee protocol. The flaw of this work is the lack of hardware system along with the short communication range of Zigbee protocol.

In ¹¹, authors present design, development and evaluation of a self-powered tracking system for vehicle security. They used 3 piezoelectric generators (PG) in cantilever beam configuration tuned to the dominant frequency of a test vehicle. However, they failed to produce a hardware system along with the management of system. Authors in ¹² discusses the accuracy enhancement of GPS track in Google Map. They design an Android based tracking system to demonstrate the geographical fit effect and the transmission cost of different report intervals.

3. Motivation

Due to growing economies of scale, the overall number of mobile assets is expected to increase as ownership becomes more affordable. However, the implementation of ubiquitous tracking system is still lacking. Vehicle tracking systems have been available in the market for some time but they are application specific, region specific and costly ^{13, 17}. Although enhancements to GSM such as the next generation systems have been rolled out to cater fast data centric traffic, backend compatibility is still preserved.

One of the fundamental issues arising in tracking system is its cost. To address this, GPS-less location algorithms using only RF signals in Wireless Sensor Networks (WSNs) for the estimation of a node position is also a possibility, but they might result in severe distance errors. Also, the limited and portable battery power is a bottleneck in WSNs. Consequently, this cannot be used for long-term, standalone and reliable tracking system. These reasons are the motives for the implementation of a low cost GPS Tracking system that can provide more functionalities than that of the existing tracking systems.

4. Proposed System Design

The proposed GPS and GSM based Vehicle Tracking System (VTS) is developed by exploring the applications of various state-of-the-art technologies to overcome the problems of traffic organization, vehicles theft and surveillance. This is a relevant, effective and efficient system in order to enhance the vehicle security and tracking. M2M communications, which is all about letting the machines talk, is being used. Our system enables machines to communicate with information systems or with other machines and provide real-time data. A wireless information link is used for monitoring and managing, with data transportation occurring either by request or at predetermined intervals. The work flow diagram of our proposed system is shown in fig. 2. The following subsections delineate different blocks of our proposed design.

4.1. Global Positioning System (GPS)

GPS has become an efficient tool in the field of scientific use, commerce engineering, surveillance of objects and tracking ¹⁹. GPS uses Trilateration process to compute the position of an object as shown in fig. 1. In our system,



Fig. 2. Work Flow Diagram

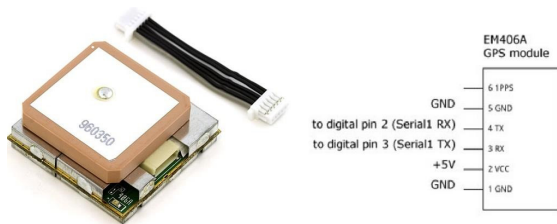


Fig. 3. (a) GPS Receiver EM406-A (b) EM406-A Pin Configuration

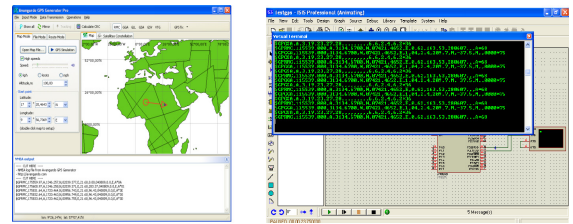


Fig. 4. (a) GPS Generator PRO (b) Proteus and Hyper Terminal

GPS is the key component in getting the assets’ coordinates for tracking. The details of GPS device that we have used in our system is given in the following subsection.

4.1.1. GPS Module EM406-A

We have used GPS receiver module EM-406A from Sparkfun²⁰. The device and its pin configuration are shown in fig. 3. This GPS module, when powered on, waits for the signal from at least 3 of the orbiting satellites in the space. Upon reception of signals successfully, it uses trilateration process to compute its coordinates as shown in fig. 1(b). For the simulations, we used Proteus®, Windows Hyper Terminal®, Virtual ComPort® and GPS Generator PRO®. The interfaces along with the software integration of these simulation tools are shown in fig. 4. Some of the significant characteristics of EM406-A are given below:

- 20 Channel Receiver with Built-in antenna, Sensitivity = -159dBm, Accuracy = 5m, Baud Rate = 4800
- Power = 44mA, DC operation = 4.5-6.5, NMEA 0183 and SiRF binary protocols (\$GPRMC)
- Hot Start = 1 seconds, Warm Start = 38 seconds, Cold Start = 42 seconds

4.2. Global System for Mobile Communication (GSM)

In our work, GSM basically keeps the owner of the mobile asset as well as the server updated. The module sends SMSs to the owner of the vehicle using a pre-defined time interval which is neither too periodic nor too overdue. Besides, the GSM module also responds to any SMS sent by the owner of the vehicle after authenticating it. The owner of the asset can ask the GSM module about the location, speed, water level, movement status, engine level, geographical limit, or all at once. In short, the owner can find the status of the vehicle with just an SMS. The owner has also been given the control to turn the vehicles engine off just by sending an SMS. The coordinates of every vehicle are also sent continuously to a standalone server running 24/7.

For the mobile phone users, they can simply send a SMS to the system installed inside their vehicles. Upon reception of the SMS, the tracking system will send a query message, packed with the objects latitude and longitude,

Algorithm 1: GSM/SMS Operation

```

if (SMS received) then
  if (user is authenticated) then
    if (user ask for location) then
      if (user has a smart phone) then
        1. s-query.ID = id of mobile number in database
        2. ask server for location name and send SMS to user
        3. send SMS to display location on Google Maps in owner’s Android Application
      else
        1. query.ID = id of mobile number in database
        2. ask server for location name and send SMS to user
      endif
    endif
  endif
endif
  
```

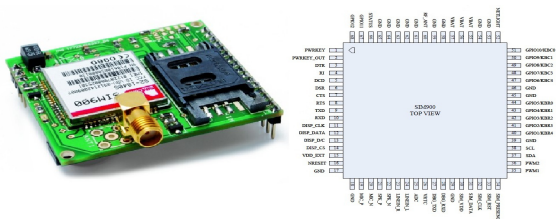


Fig. 5. (a) GSM Modem SIM900-D (b) SIM900-D Pin Configuration

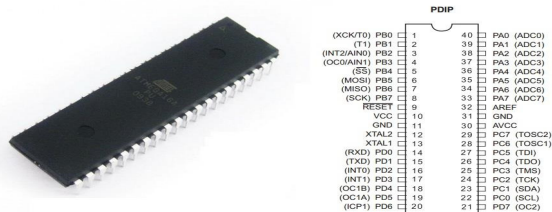


Fig. 6. (a) Microcontroller ATmega-16 (b) ATmega-16 Pin Configuration

to the server asking for the location name. The server after performing the implemented method, and with the help of Google Maps, will send back an SMS to the tracking system about the location name being asked. The tracking system, in the interim, will also be capable of entertaining multiple queries by assigning IDs to each query. If the user has a smart phone, the tracking system will send a SMS to the owner smart phone, and upon reception of that SMS, the coordinates will be plotted on an Android based self-developed application without the need of internet data. Algorithm 1 defines the methodology of how the system will work in case of mobile phone users asking for the name of objects location.

4.2.1. GSM Modem SIM900-D

We have used GSM modem from SIMcom²¹. The device and its pin configuration are shown in fig. 5. Some of the significant characteristics of SIM900-D are given below:

- Frequency = (850, 900, 1800, 1900) MHz
- Current = 40 mA, Voltage = 3.2-4.8 V
- SMS Sending/Receiving, Voice Calls, GPRS supported, Baud rate = {4800, 9600 and so on... }

4.2.2. Special Security Button

Our system is equipped with a special security button which will be installed inside the vehicle near the driver seat but at a hidden place so that only the driver, or owner, of the vehicle knows the location and functionality of button. Whenever the vehicle will be parked at some place, the user can turn this button ON to provide full boost of security. Upon turning this button ON, the tracking system will come in ACTIVE mode to keep the security of mobile asset tight. In ACTIVE mode, the tracking system will know that the vehicle is parked or in a status of no motion and, therefore, should have a speed of almost 0 mph (the term almost 0, keeping in mind the uncertainty of GPS along with the earth relative rotation). If the speed of the object crosses a pre-defined threshold, the system will sense motion, and will alert the owner immediately. The system will turn the main ignition off and will send 5 SMSs to the owner. With this feature, our system provides extra tight security for a mobile vehicle.

4.3. Microcontroller (μC)

A microcontroller is a computing device which usually consists of built-in peripherals. It included CPU, USART (Universal synchronous asynchronous Receiver Transmitter), timers, counters and other components.

4.3.1. Microcontroller ATmega-16

In our work, we have used the ATmega-16 microcontroller of the Atmel®family²². The device and its pin configuration are shown in fig. 6. C/C++ and assembly language is used to program the microcontroller. The welcome message displayed at the start of system power on is shown in fig. 7. The flowchart of our system and its programming implementation is shown in fig. 9. Some of the significant characteristics of ATmega-16 are given below:

- 8 bit Microcontroller, RISC Architecture, 32 × 8 General Purpose Working Registers
- EEPROM = 512B, Internal SRAM = 1 KB, In-System Flash program memory = 16 KB
- 32 Programmable I/O Lines, Peripheral Features



Fig. 7. Displayed Message on LCD

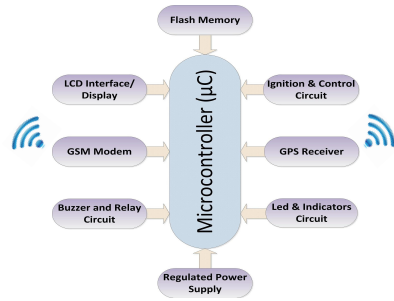


Fig. 8. System Block Diagram

4.4. Additional Components

Along with the major modules and components, a number of other components are also used in our project. Some of them are listed below:

- 16 × 2 LCD Display & 12V Battery
- LEDs, Buzzers, Indicators, Relays
- MAX 232 IC, Voltage Regulators & Other Electronic Components

4.5. System Integration

The overall system consists of three layers of closely and safely connected PCBs. The block diagram of the system is shown in fig. 8. All the three blocks are mounted and fabricated on three different layers of PCB so as to avoid the inter-component interference. The three layer PCB design circuitry is shown in fig. 10. As shown in the figure, fig. 10 (a) presents the circuitry of µC-Control block; fig. 10 (b) shows the circuitry of GSM-Communication block, fig. 10 (c) shows the circuitry of GPS-Tracking block and fig. 10 (d) shows the final integrated working hardware design of our system. The cost of our system is approximately 80 USD which is much less than the existing tracking systems and, hence, makes it a very economical system.

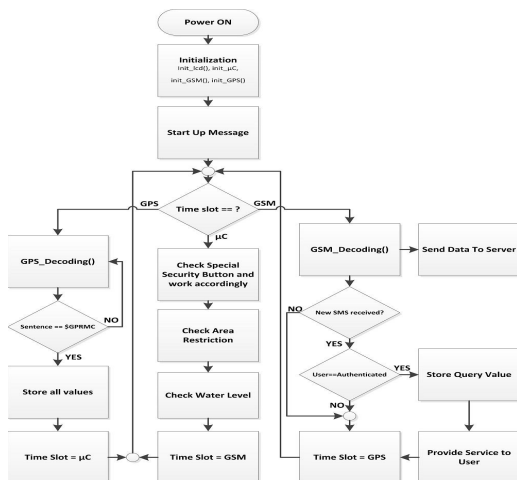


Fig. 9. System and Programming Flow Chart

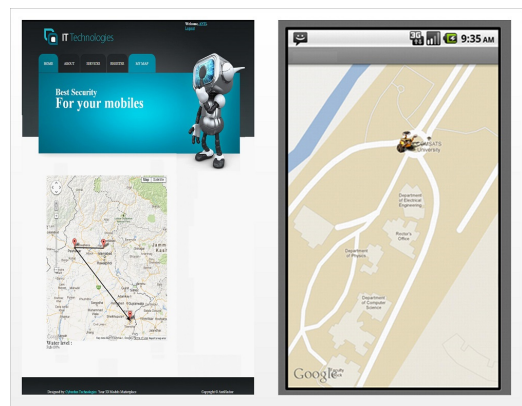


Fig. 10. (a) Web Portal Interface (b) Android Application Interface

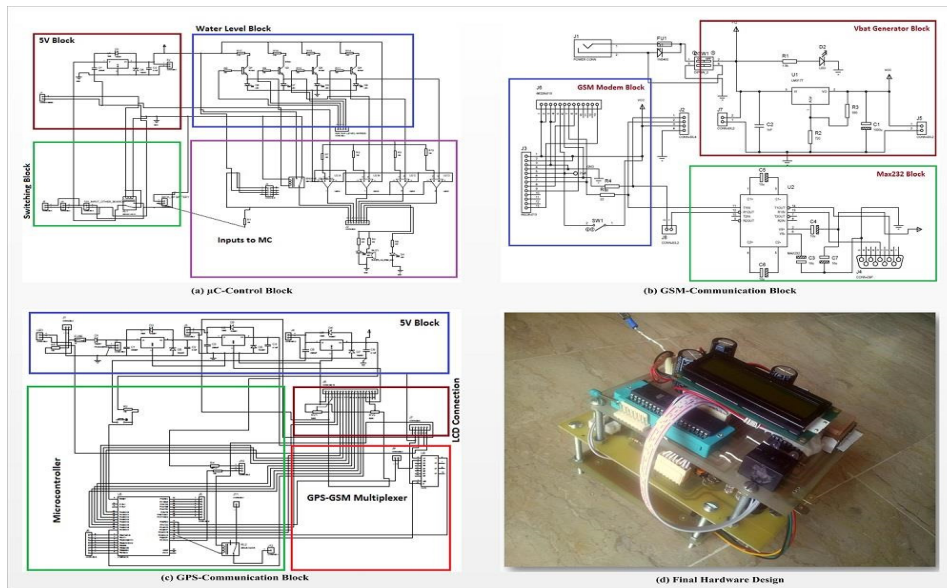


Fig. 11. (a) μ C-Control Block (b) GSM-Communication Block (c) GPS-Tracking Block (d) Final Hardware Design

4.6. Web Portal

For giving a complete view, we have developed a website in which only authenticated user will be having access to his/her vehicle. The user can see the location, movement track, speed, different parameters and other sensor measurements which can be interfaced with the system later on. In developing this website, we have used Adobe Dreamweaver®, WAMP Server® and HTML/CSS/PHP web languages. In our system, PHP coding is done in the login-system where only authenticated user will be given services. In addition, it is also implemented in map displaying in which the vehicle movement is displayed on map. For the map we used Google API. Fig. 11 (a) shows the web portal interface that we developed in our work.

4.7. Android Application

The Android mobile application, as shown in fig. 11 (b), is the second client of our system. This application makes our proposed system much more efficient than the already developed systems. With this application, the smart phone users can see the track of their assets on a android application without the need of internet data.

5. Results and Analysis

We have successfully implemented our system that showed effective results. We tested our system a number of times and then we deployed it in real time to check a vehicles record. The tracking system was installed inside a car and the car travelled 3 cities. The tracking system was continuously asked for the statuses at intervals and it responded every time successfully. It can be seen in fig. 11 (a) that the travelled path has been highlighted on the web portal using Google Maps. The red pin drops show the starting and finishing spots of vehicle at three different cities.

For the purpose of analysis, we visited a number of tracking companies and compared our features with theirs. Our system beats the already developed tracking systems on the basis of overall cost, control, services, portability, reliability, authentication and 24/7 facilities.

None of the above mentioned features are been given in the papers^{5, 6, 7, 8, 9, 10, 11, 13}. Consequently, our system design turns out to be the most efficient, robust and powerful tracking system design with a number of features to offer along with the already mentioned.

6. Conclusion

This paper presents a GPS and GSM based vehicle tracking system that provides the owner of a mobile asset with full security and track of the asset. The system allows users to track the position, speed, water level, engine level and different parameters. The owner of the vehicle just has to send an SMS and the tracking system installed inside the vehicle will respond within a minute. The system is equipped with a backup battery in case of a smart thief.

Our proposed system design works continuously and offers services 24/7. We have also developed a web portal for the users to track their vehicle on internet, and an android application for smart phone users, with which they can easily track their vehicles on Google Maps without the need of internet. The results show that our system outperforms the traditional existing tracking systems in terms of cost, services, reliability and control.

Acknowledgments

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